



quarterly **a**nalysis review

18.1

1Q 2018

| | |
|--------------------|---|
| vto | kelly fleming, rachael nealer, jake ward |
| anl | josh auld, amgad elgowainy, dave gohlke, jarod kelly, eric rask, aymeric rousseau, tom stephens, michael wang, joann zhou |
| energetics | alicia birky |
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| ornl | stacy davis, zhenhong lin |
| nrel | aaron brooker, jeff gonder, marc melaina, matteo muratori, mark singer, eric wood |
| snl | brandon heimer, becky levinson, nesty ray torres, todd west |
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26 march 2018

topics

1

energy markets

automotive markets

technologies studies

environmental studies

behavior & opinion surveys

policy & business studies

qar

outline

1 energy markets

oil production

- > EIA: Domestic oil production is at the highest point in decades
- > FOTW: Texas, North Dakota, and the Gulf of Mexico account for most domestic crude production

energy markets/production

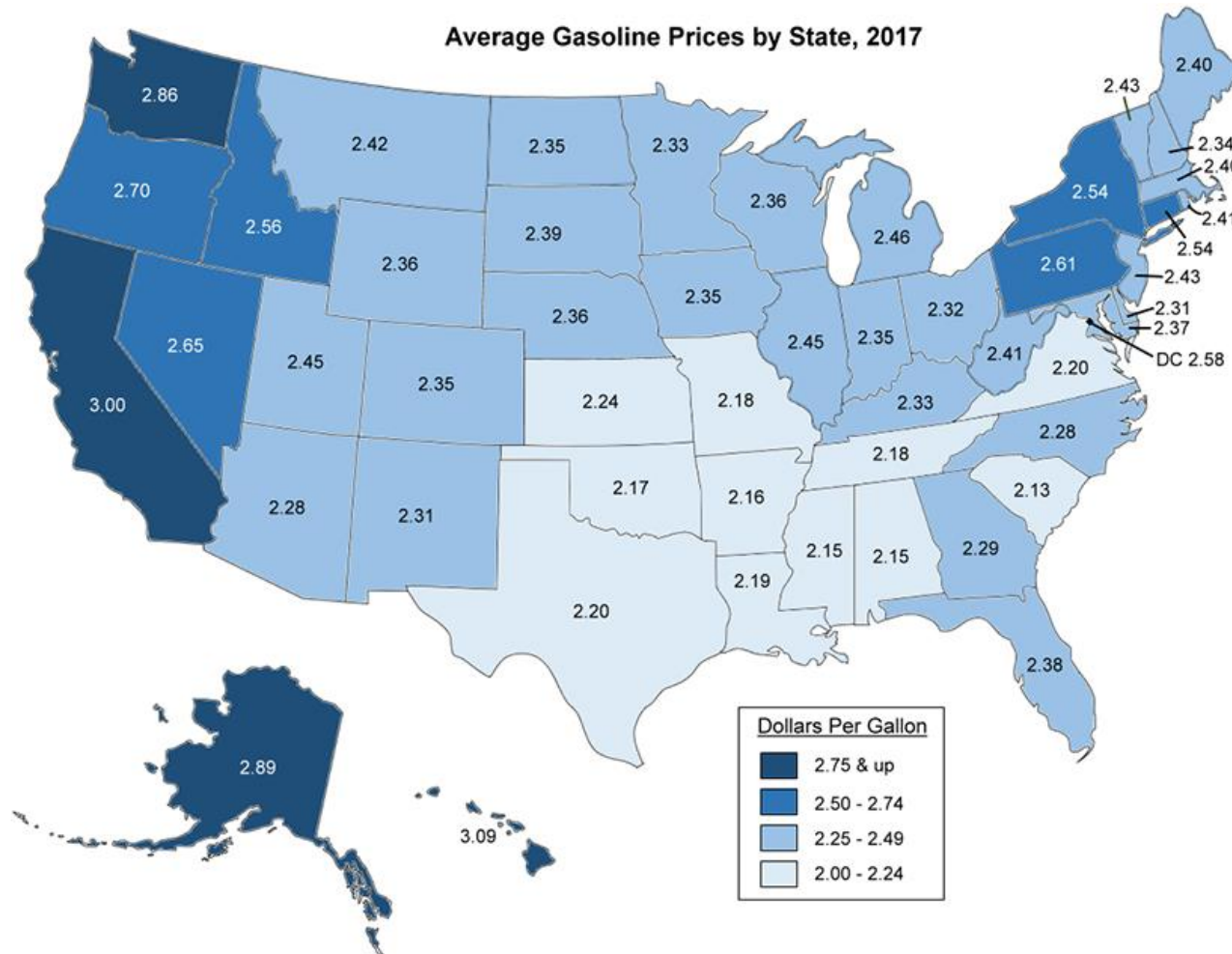
- > FOTW: On-road vehicles consume most of U.S. transportation energy
- > EIA, ExxonMobil, BP: Demand for energy will grow in next decades, somewhat offset by improvements in energy efficiency

high-octane fuels

- > EIA: The price difference between regular and premium gasoline continues to increase
- > EIA: Ethanol and bio-diesel production are at record high levels

gasoline prices

FOTW: Gasoline prices are generally the highest in the West and lowest in the South Central



oil production

EIA: U.S. monthly crude oil production of 10 mbpd is highest level since 1970

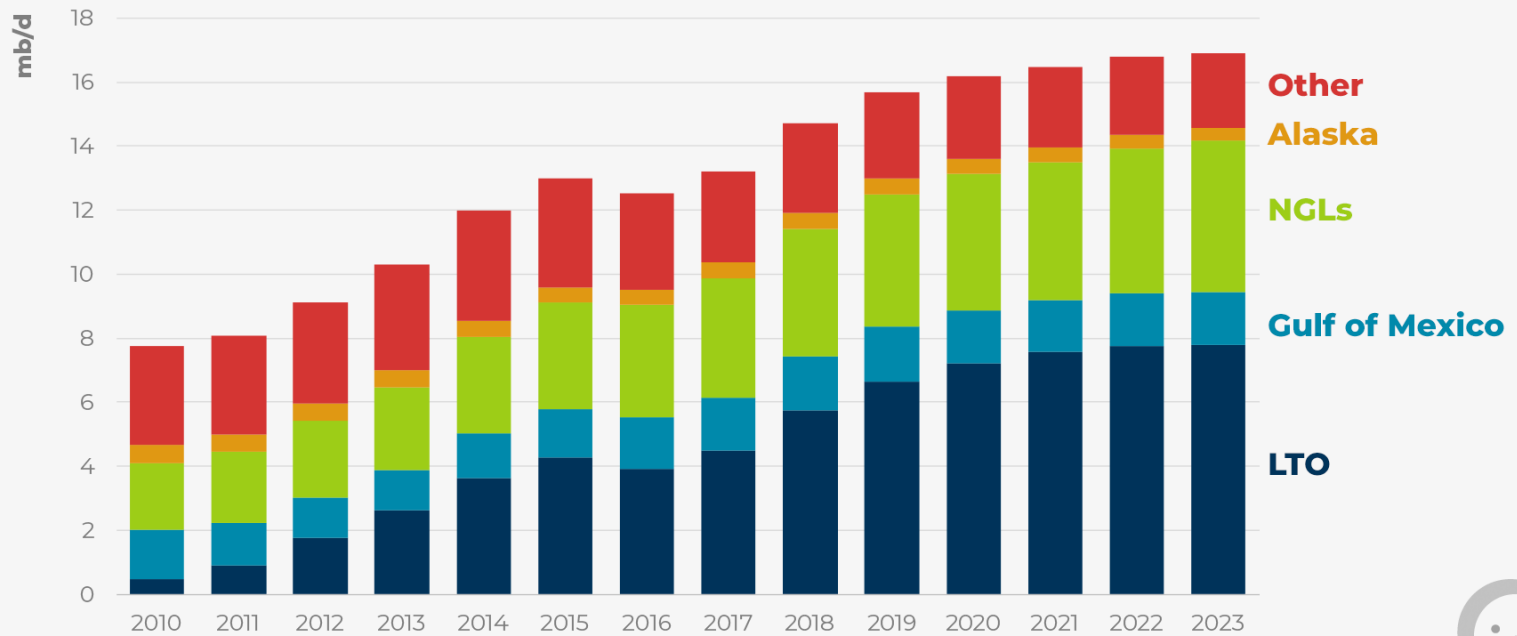
U.S. monthly crude oil production (Jan 1920- Nov 2017)
million barrels per day (b/d)



oil production

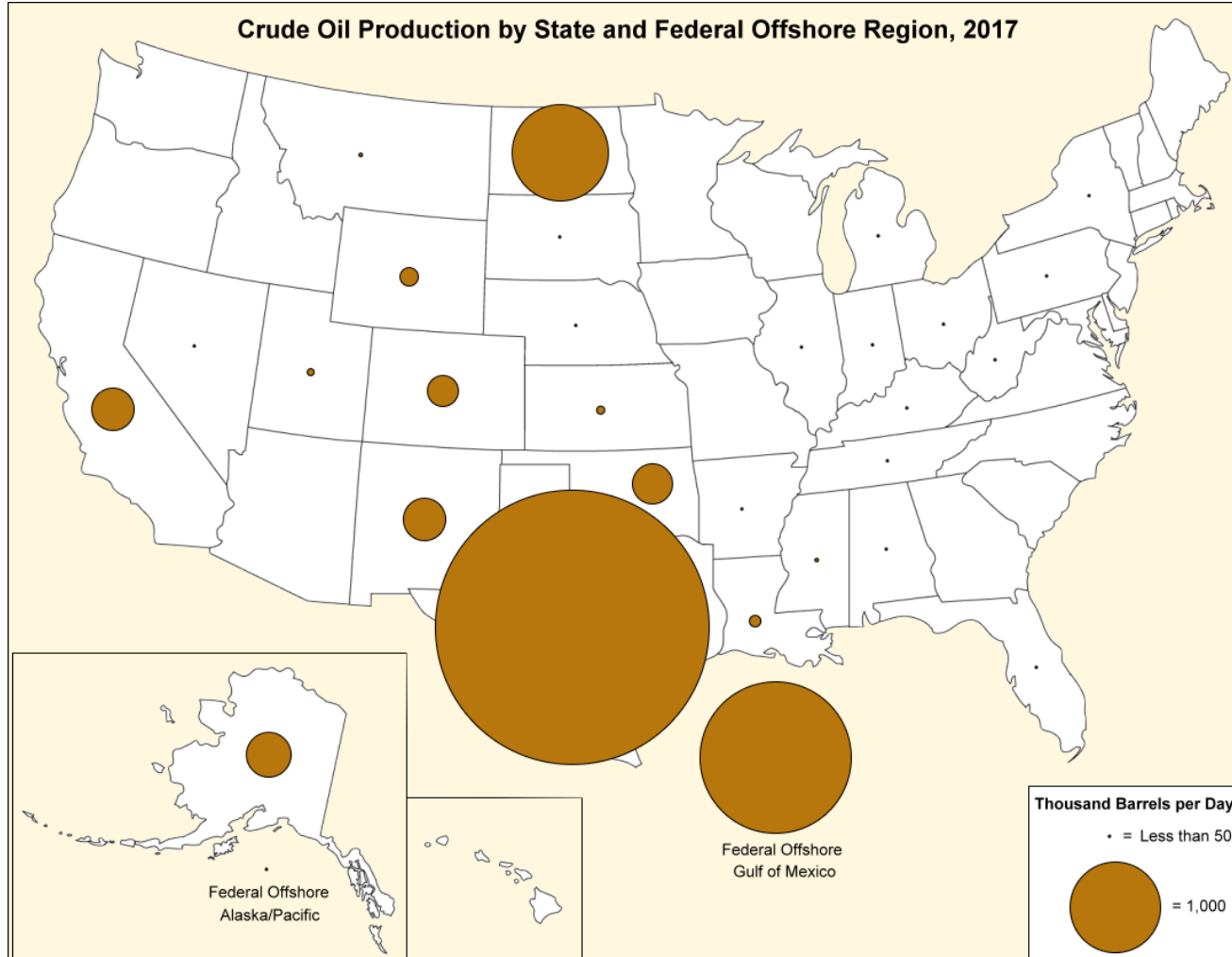
IEA: Light tight oil will be half of U.S. oil production by 2023

United States oil supply, 2010-23
Oil 2018



oil production

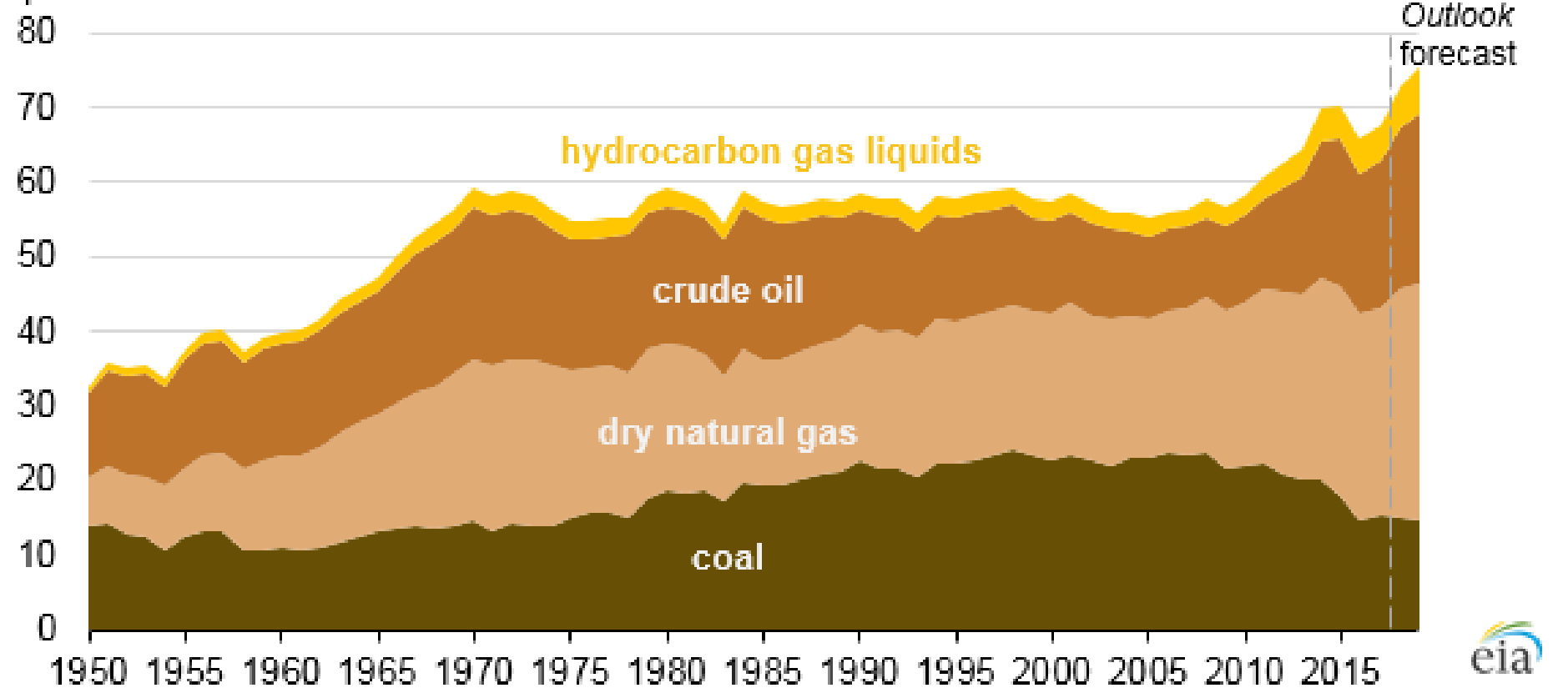
FOTW: Texas, North Dakota, and the Gulf of Mexico account for 2/3 of U.S. crude oil production



oil production

EIA: Record levels of U.S. fossil fuel production are projected in 2018 and 2019

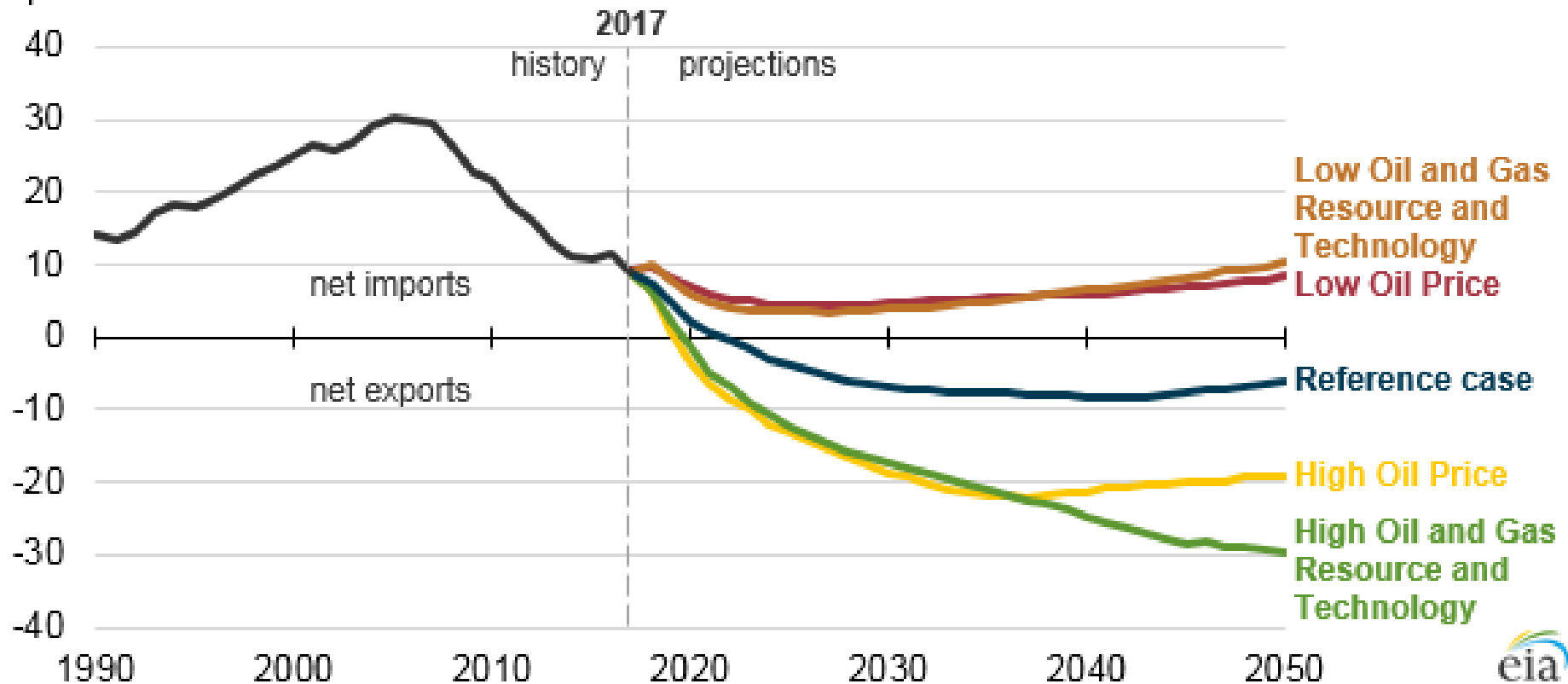
U.S. total fossil fuel production (1950-2019)
quadrillion British thermal units



oil markets

EIA: The United States is projected to become a net energy exporter in most AEO2018 cases

U.S. net energy trade (1990-2050)
quadrillion British thermal units

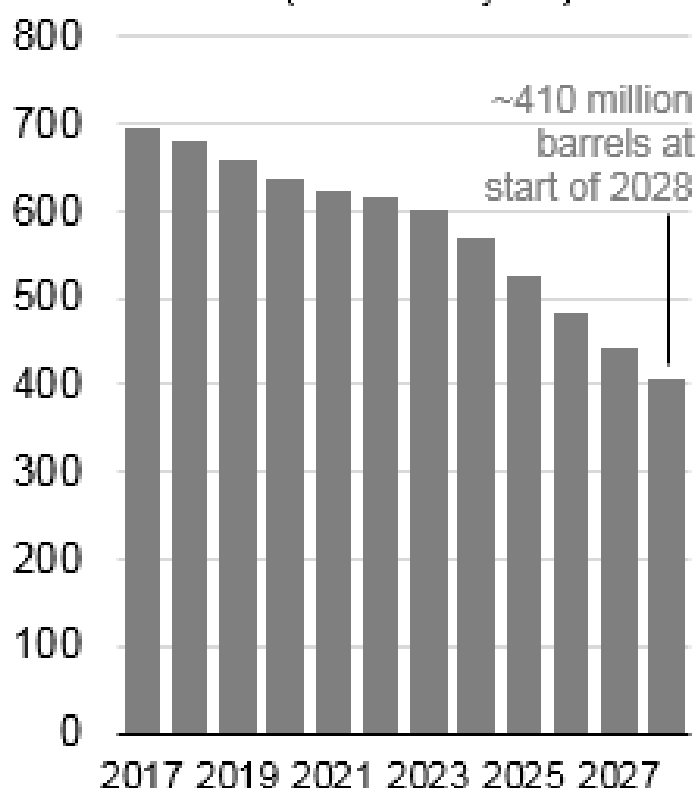


oil markets

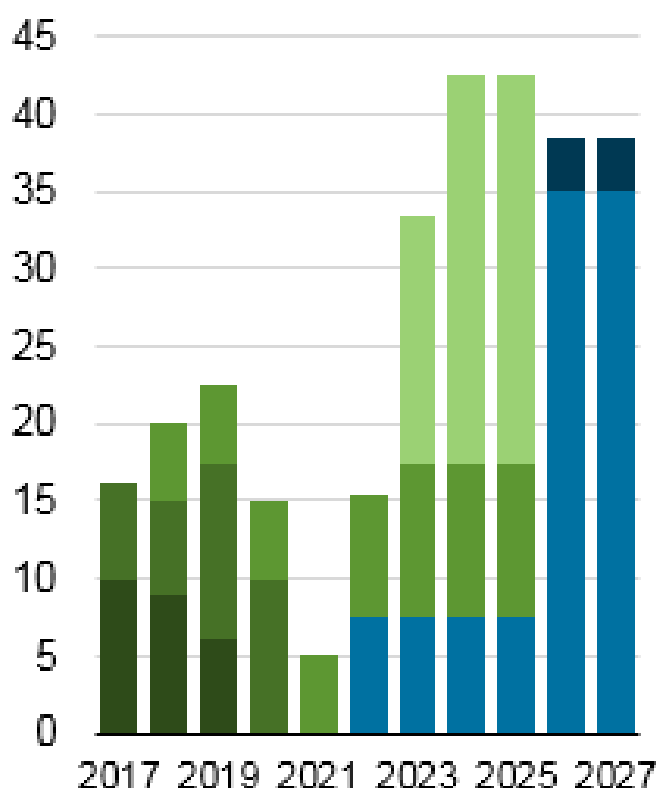
EIA: Recent legislation mandates additional sales of crude oil from the Strategic Petroleum Reserve

Strategic Petroleum Reserve inventories and planned sales (2017-2028)

million barrels (at start of year)



million barrels



21st Century Cures Act

Bipartisan Budget Act of 2015

Section 404
Section 403

Fixing America's
Surface Transportation
Act

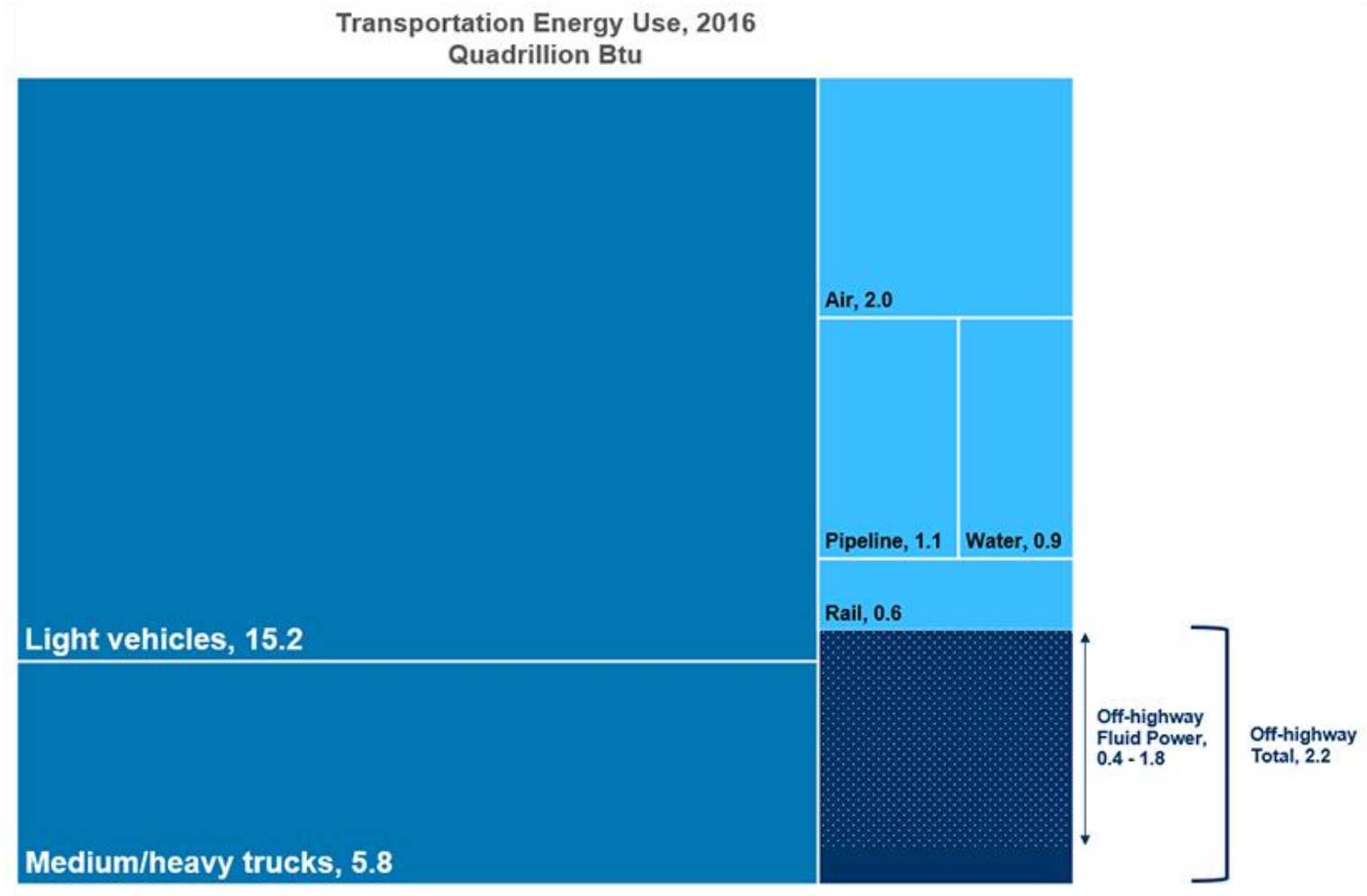
Bipartisan Budget Act
of 2018

Tax Cuts and Jobs Act



energy demand

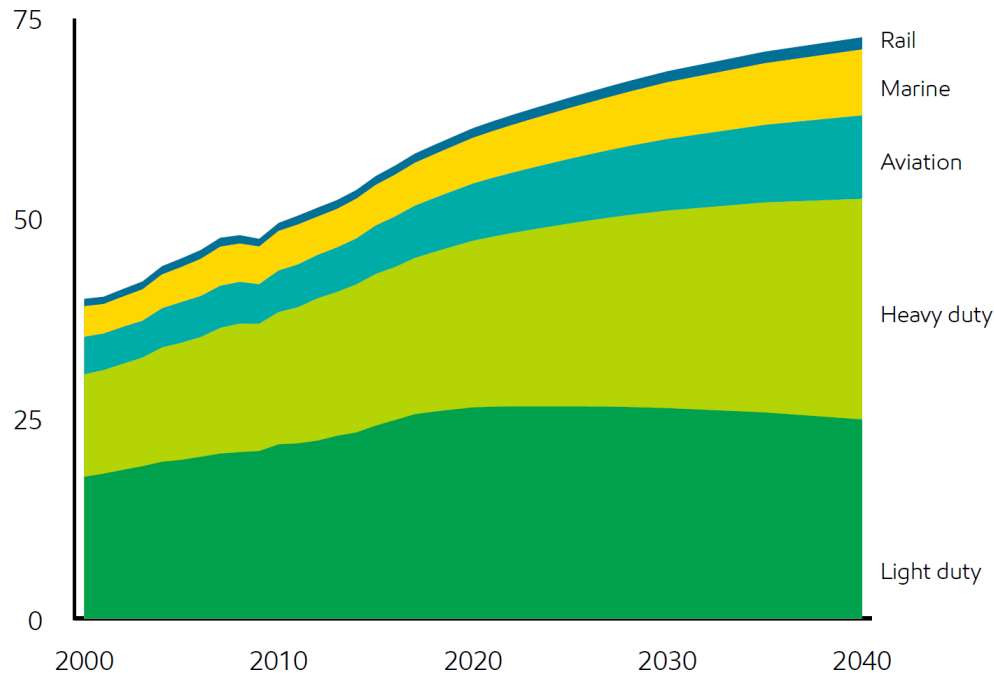
FOTW: On-road vehicles are responsible for 75% of transportation energy use in the United States



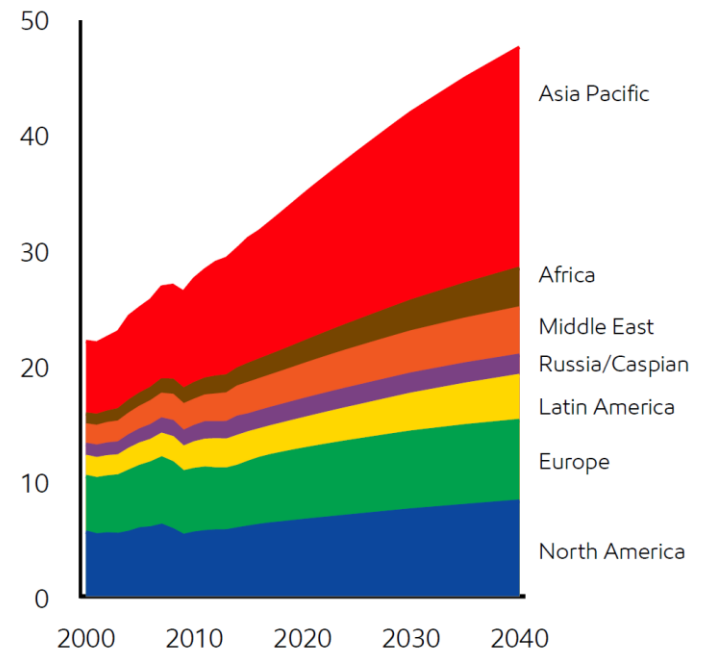
energy demand

ExxonMobil: Transportation energy demand growth through 2040 is driven by commerce

Transportation energy demand growth driven by commerce
Global sector demand – million oil-equivalent barrels per day (MBOE)



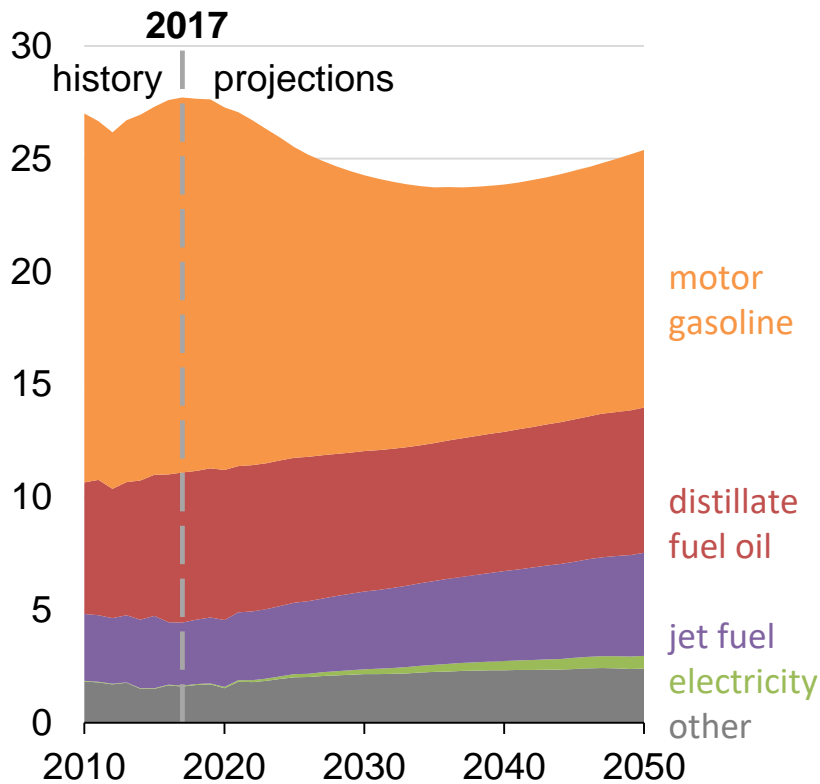
Commercial transportation grows in all aspects
Commercial transportation energy demand – MBOE



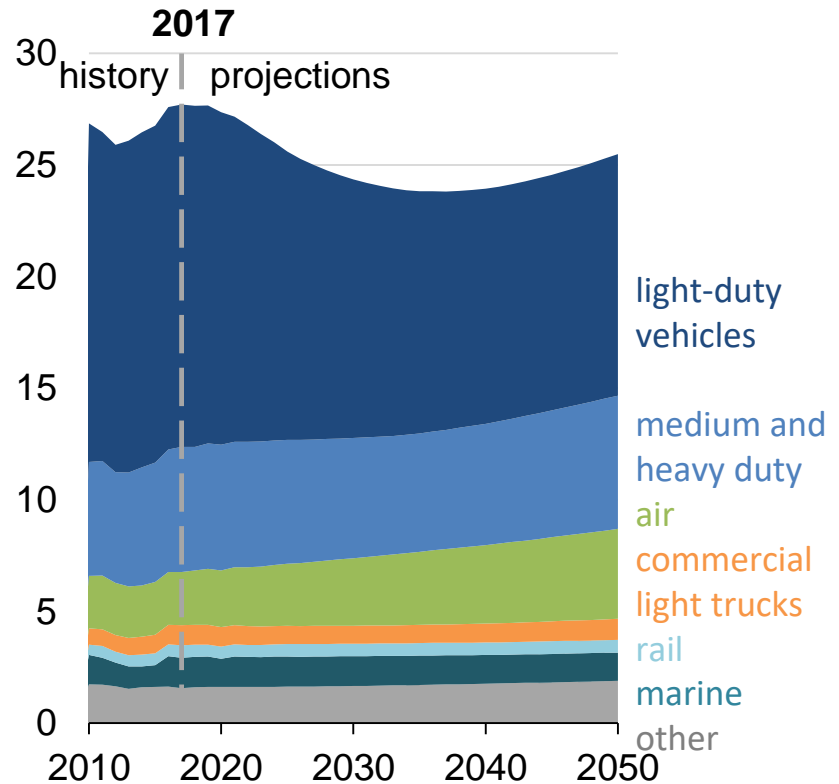
energy demand

➤ **EIA (AEO 2018): Transportation energy consumption will decline through 2035 because increases in fuel economy more than offset growth in VMT**

Transportation sector consumption by fuel type
quadrillion British thermal units



Energy consumption by travel mode
quadrillion British thermal units



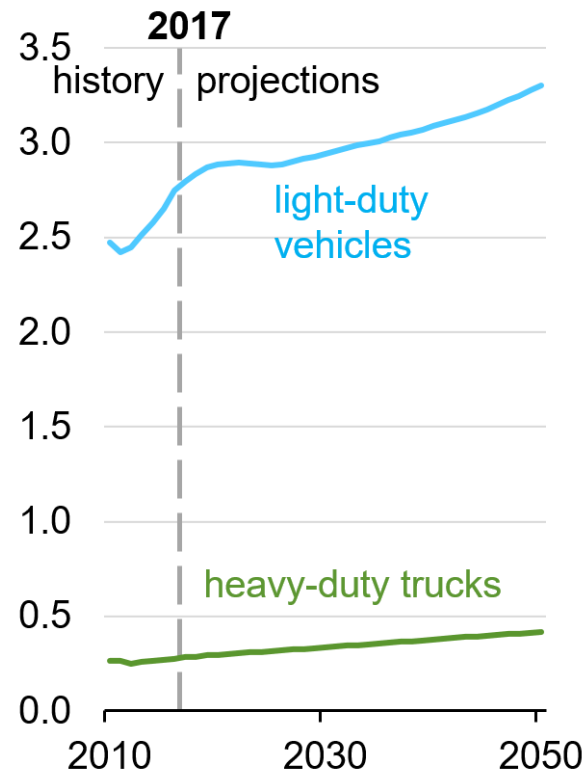
energy demand

EIA (AEO 2018): VMT projected to grow through 2050

Transportation travel statistics

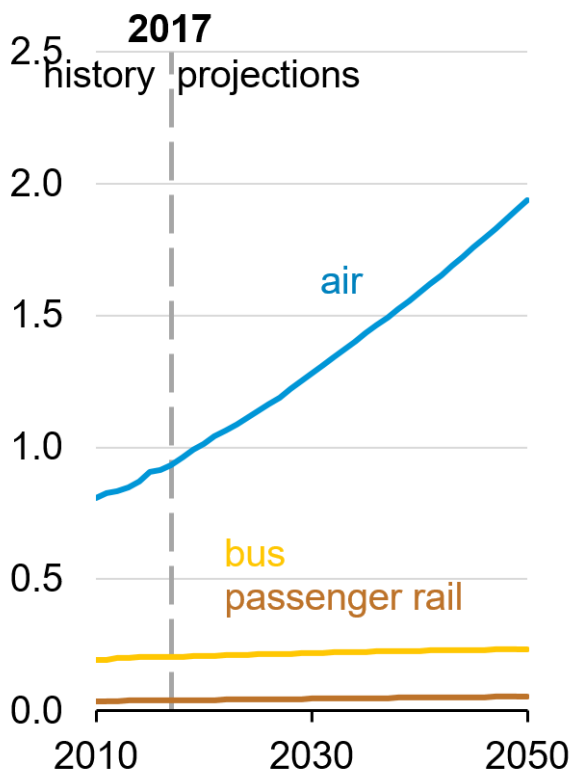
vehicle travel

trillion vehicle miles



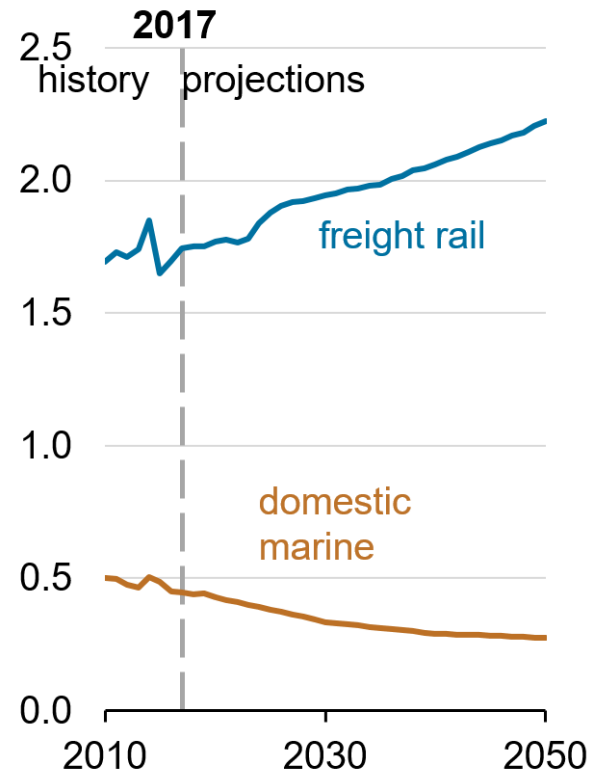
passenger travel

trillion passenger miles



rail and domestic shipping

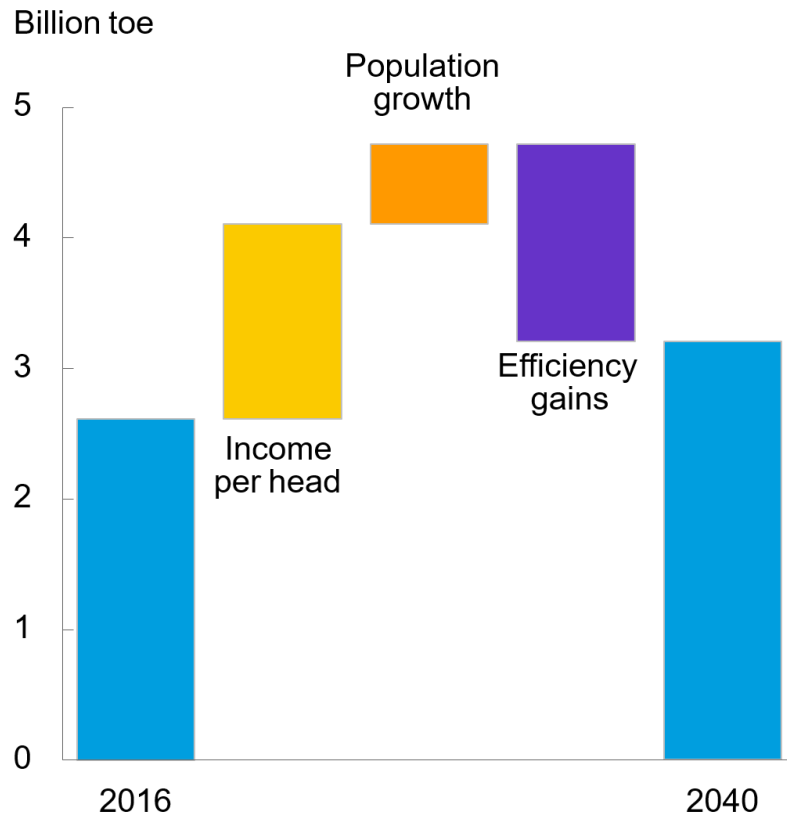
trillion ton miles traveled



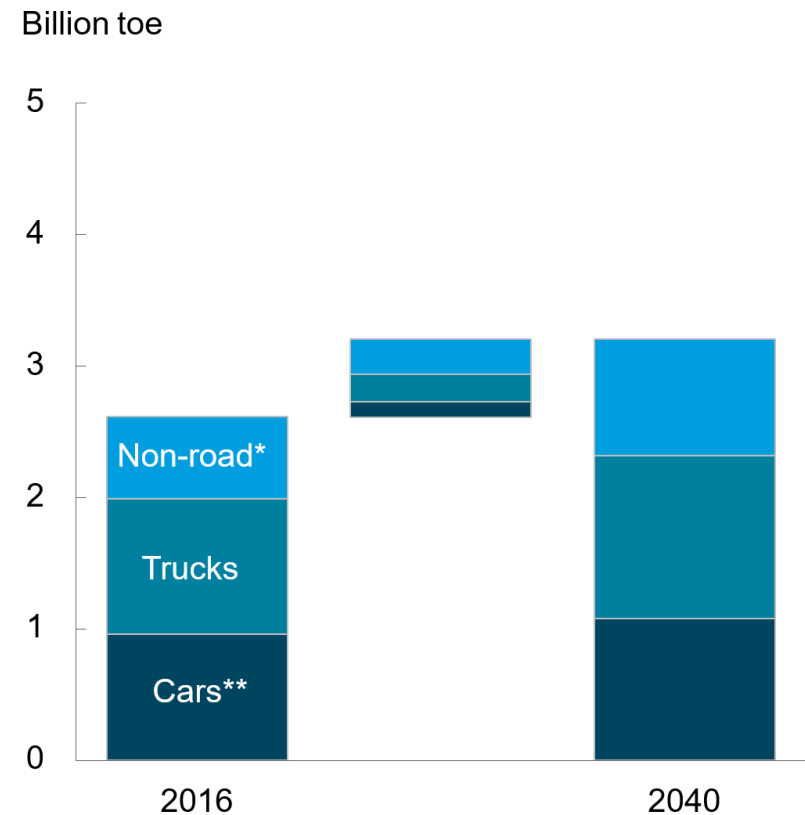
energy demand

BP: Growth of fuels used in transport grows as the impact of rising prosperity is offset by efficiency gains

Contributions to transport energy consumption growth



Transport energy consumption by mode



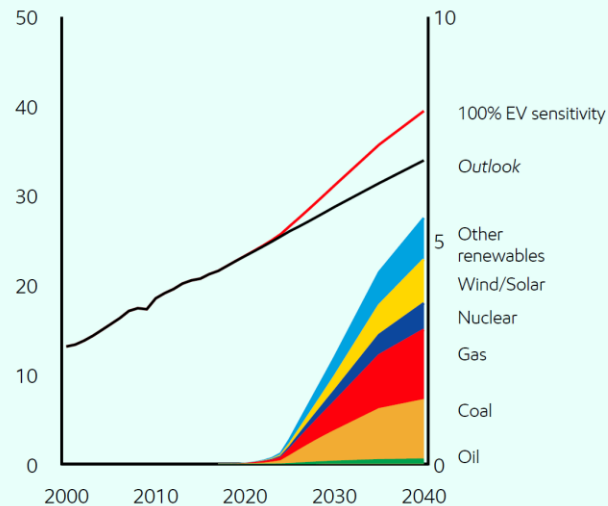
*Aviation, Marine and Rail

energy demand

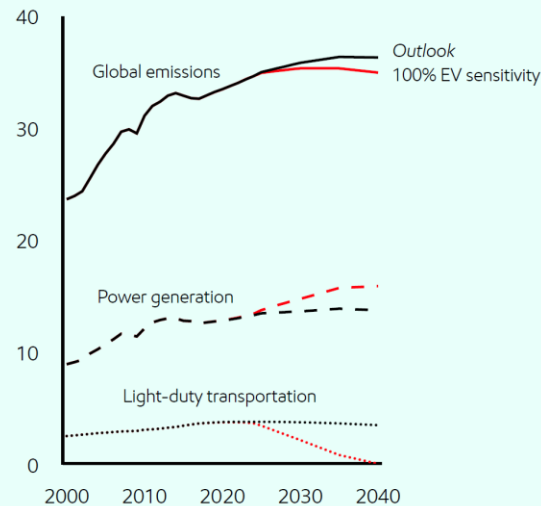
ExxonMobil: A 100%-BEV future would lead to an increase in natural gas generation

Electricity demand
World – thousand TWh

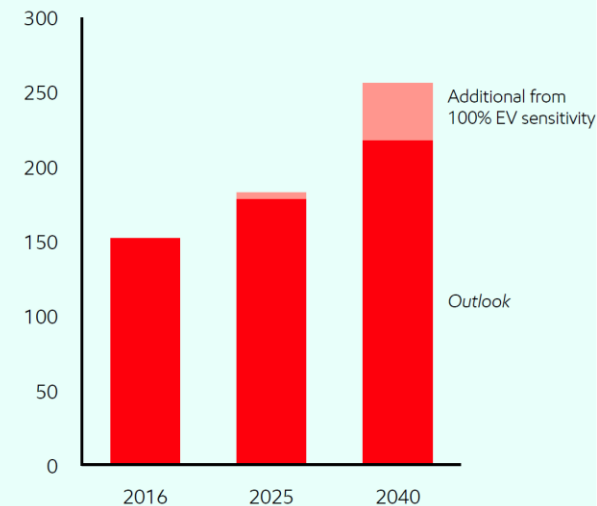
Demand increase
World – thousand TWh



Energy-related CO₂ emissions
World – billion tonnes



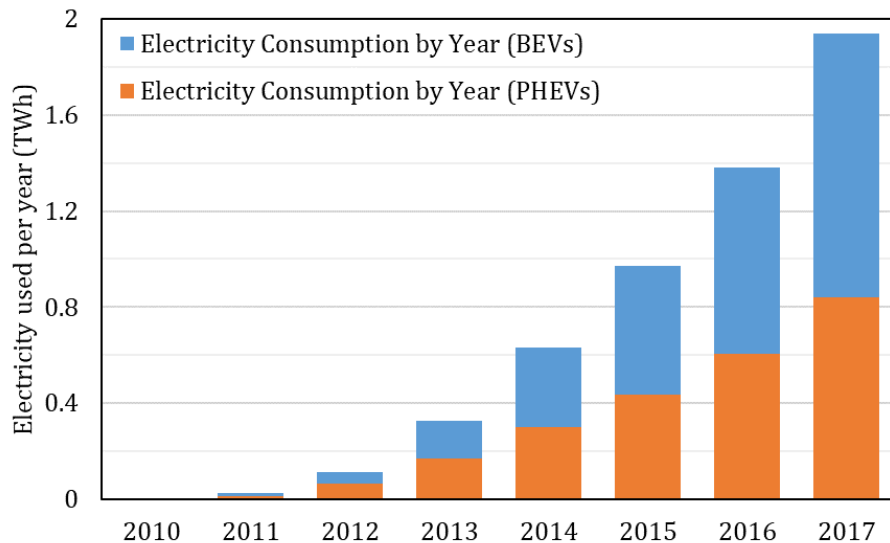
Natural gas demand increases
World – gas into power generation – BCFD



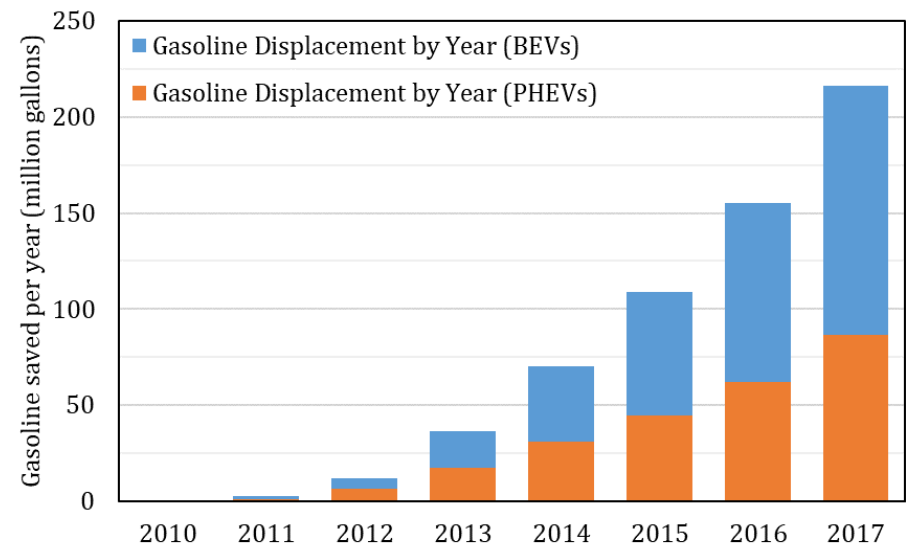
PEV impacts

ANL: PEVs in the United States have used over 5 TWh of electricity and offset 600 million gallons of gasoline

Electricity Consumption by PEVs by Year



Gasoline Displacement due to PEVs by Year

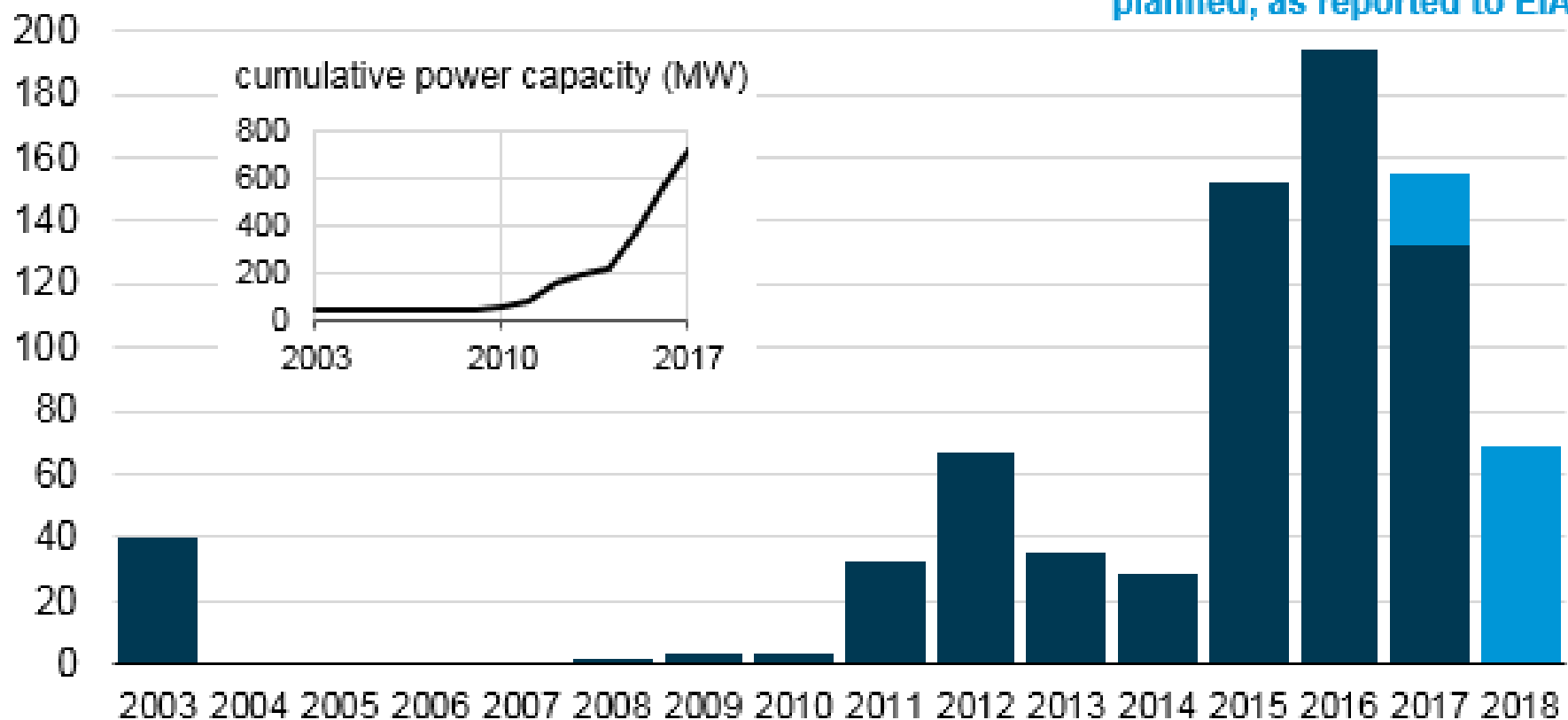


grid reliability



EIA: Utility-scale battery installations have grown rapidly in last three years

U.S. utility-scale annual battery installations, 2003-2018
power capacity, megawatts (MW)

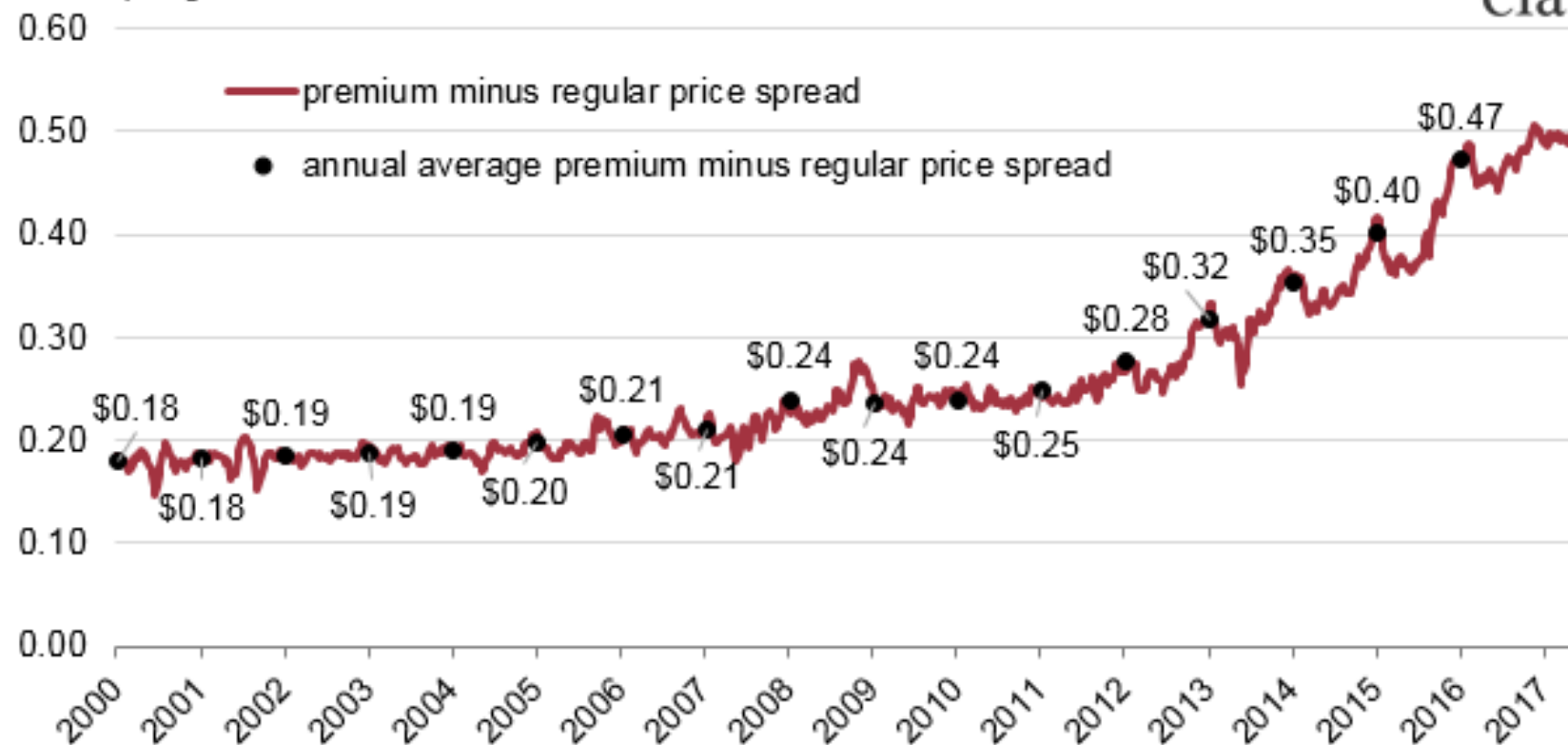


high-octane fuels

EIA: Growing octane needs widen the price spread between premium and regular gasoline

Figure 1. Retail gasoline price differential

dollars per gallon

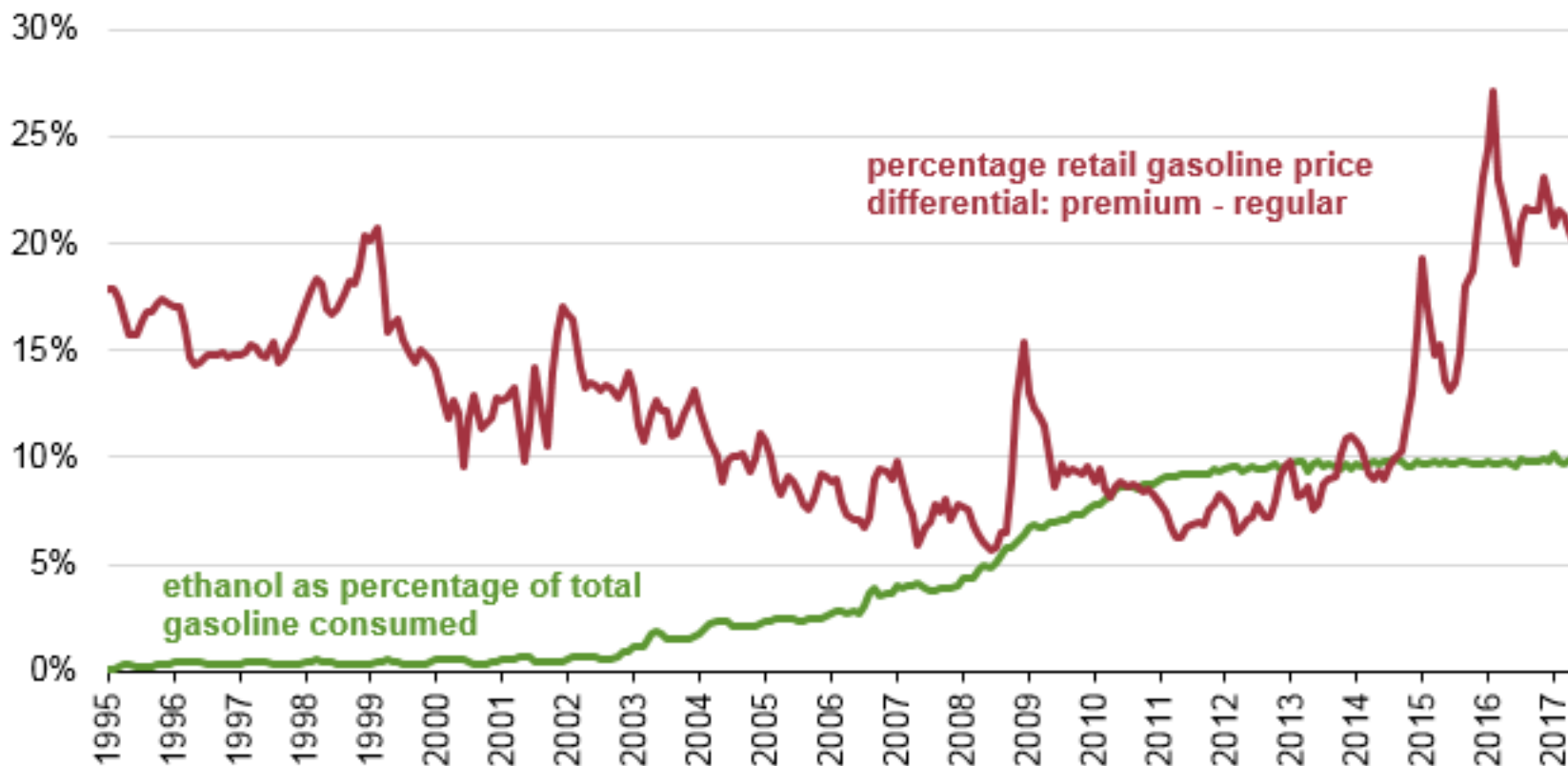


Source: U.S. Energy Information Administration, Gasoline and Diesel Fuel Update.

high-octane fuels

EIA: Price difference between regular and premium gasoline increased as ethanol reached 10% of gasoline

Figure 2. Retail gasoline price differential and ethanol blending percentages



Source: U.S. Energy Information Administration, Gasoline and Diesel Fuel Update, *Petroleum Supply Monthly*.



high-octane fuels

EIA: Positive U.S. ethanol margins are driving ethanol production growth

Estimated ethanol producer margin
dollars per gallon

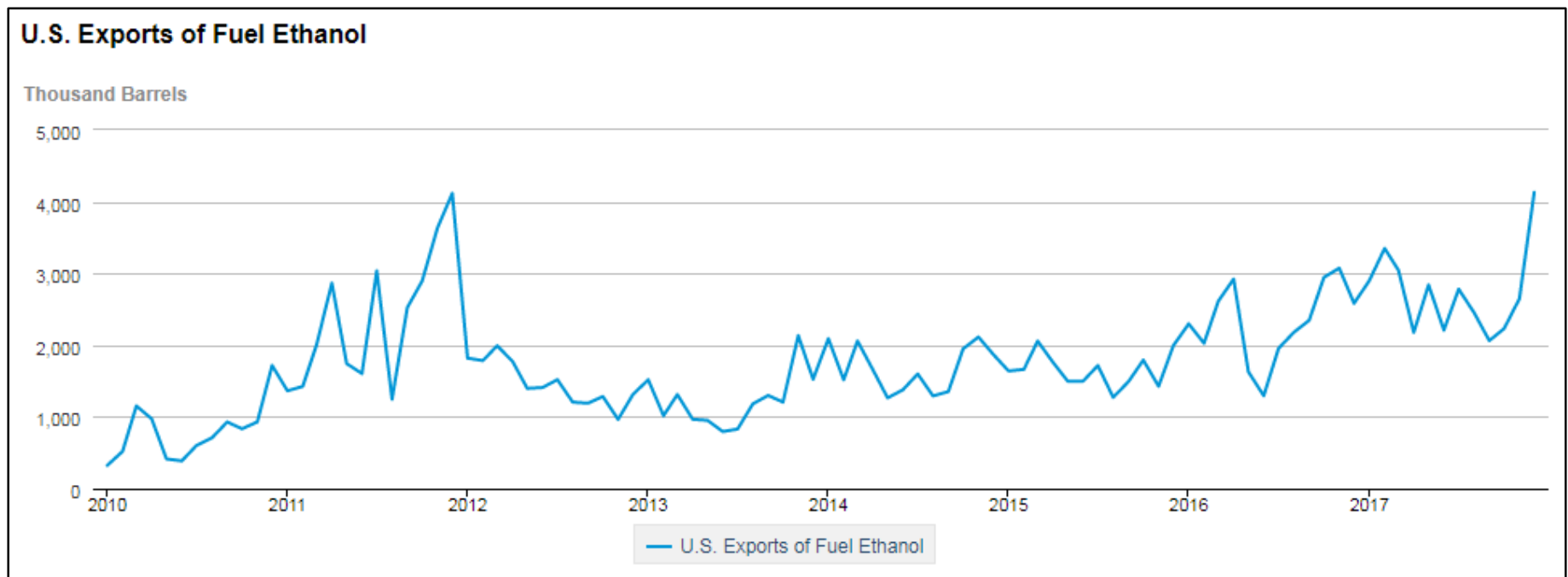


Ethanol production
thousand barrels per day



high-octane fuels

EIA: Ethanol exports hit record high in December 2017 at over 4 million barrels



topics

energy markets

2 automotive markets

technologies studies

environmental studies

behavior & opinion surveys

policy & business studies

qar
outline

2 automotive markets

LDV market

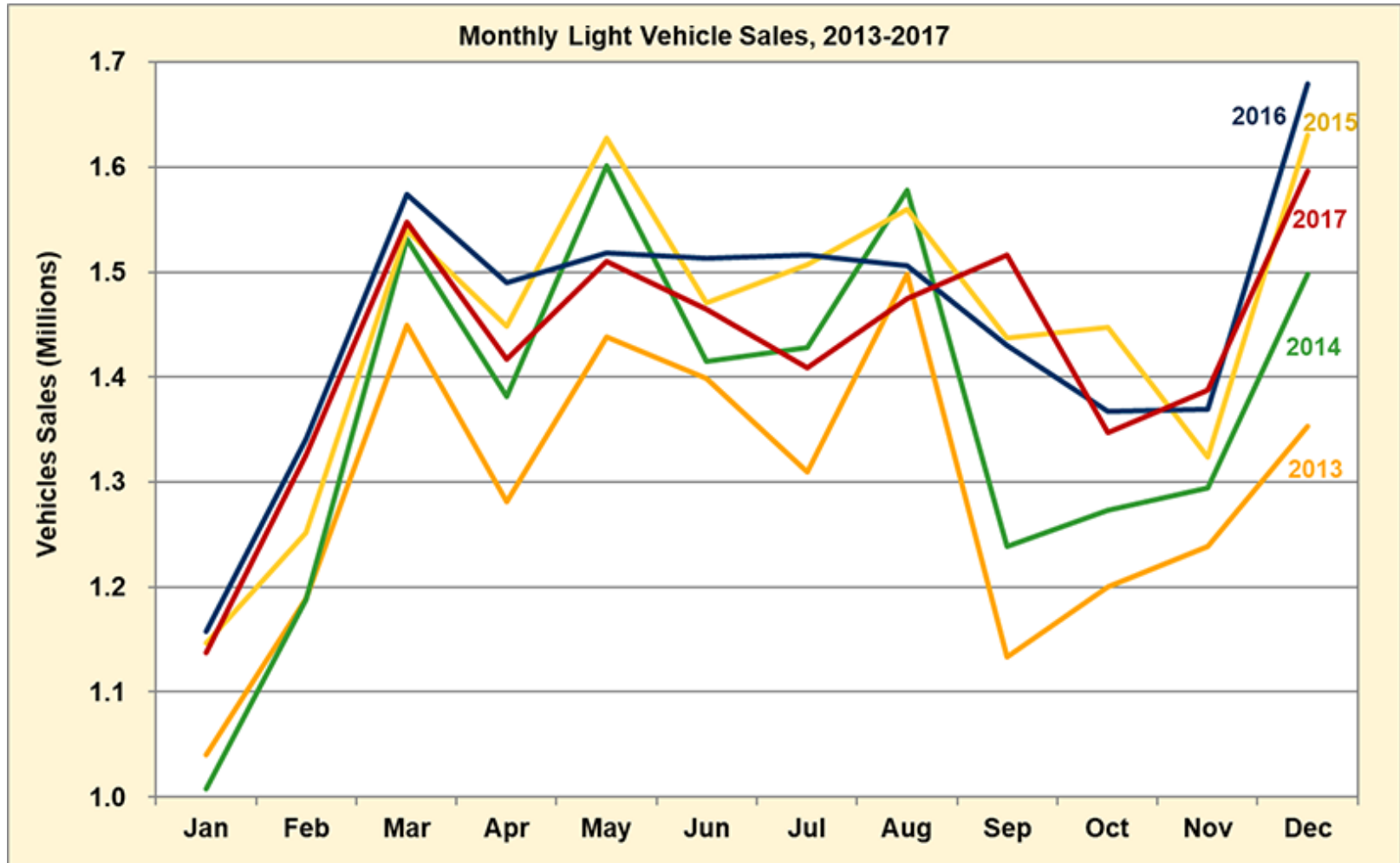
- > FOTW: New LDV sales are slightly below last year
- > Edmunds: Used LDV sales are at new record high

PEV market

- > ANL/EV Volumes: Sales of plug-in electric vehicles set all-time highs in the United States and worldwide

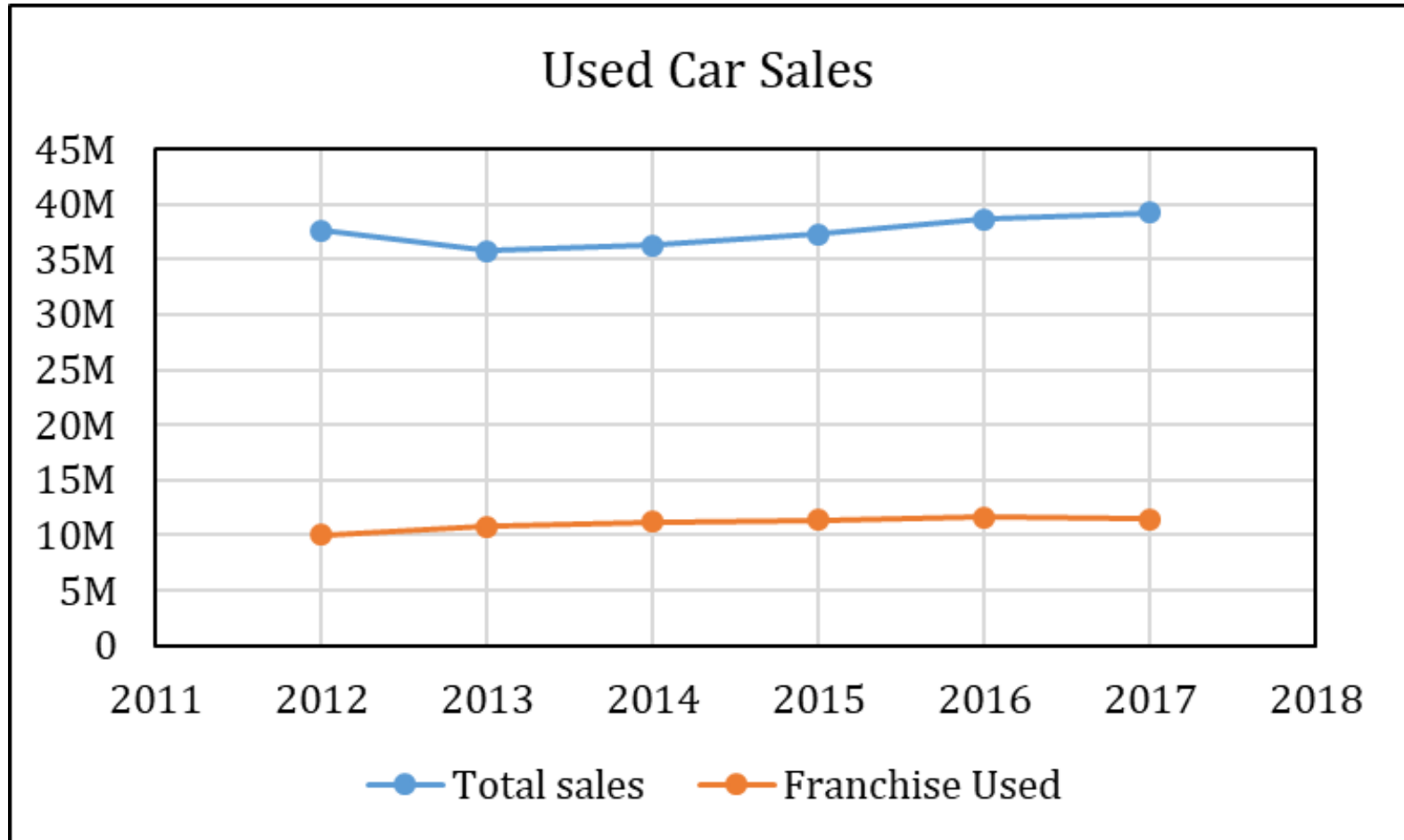
LDV market

FOTW: New LDV sales in U.S. were slightly down in 2017 from previous year's record-setting sales



LDV market

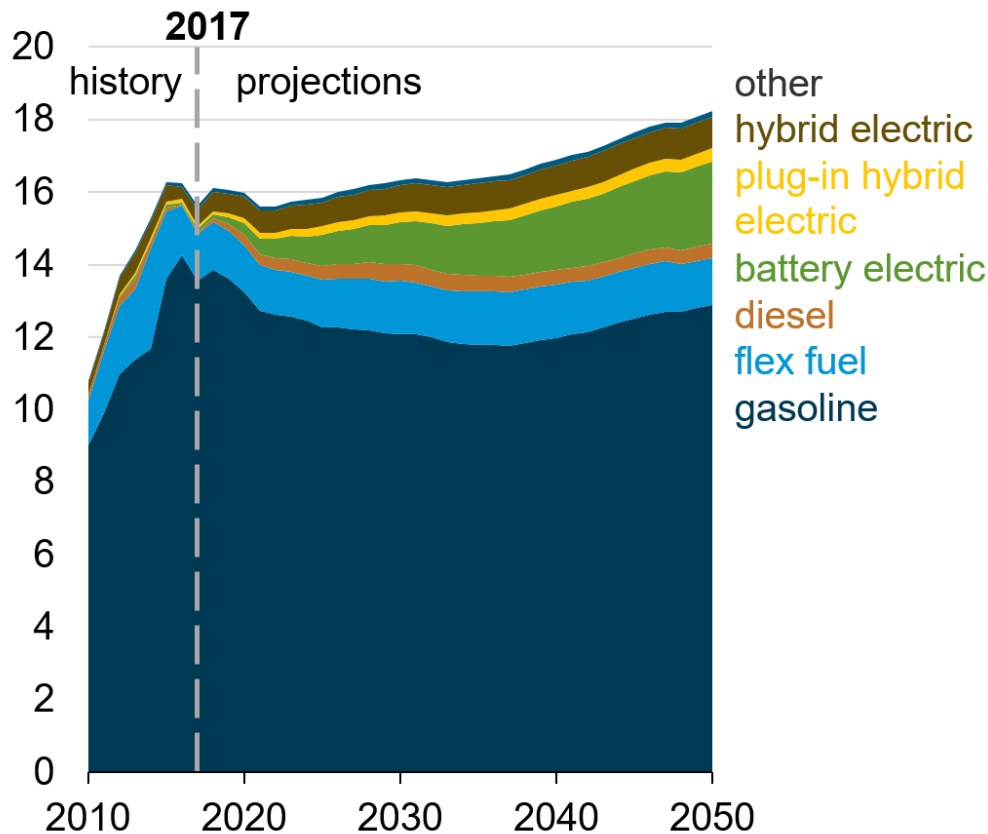
Edmunds: Nearly 40,000,000 used vehicles were sold in 2017 in the United States, a new record high



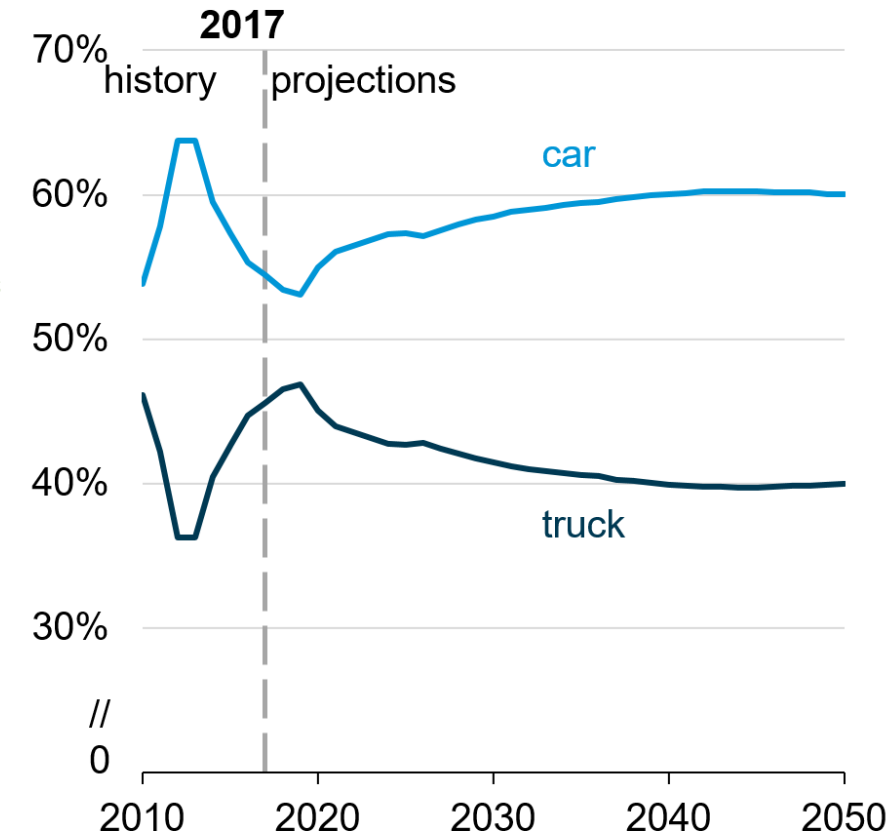
LDV market

EIA (AEO 2018): Gasoline vehicles are projected to be dominant through 2050

Light-duty vehicle sales by fuel type
millions of vehicles

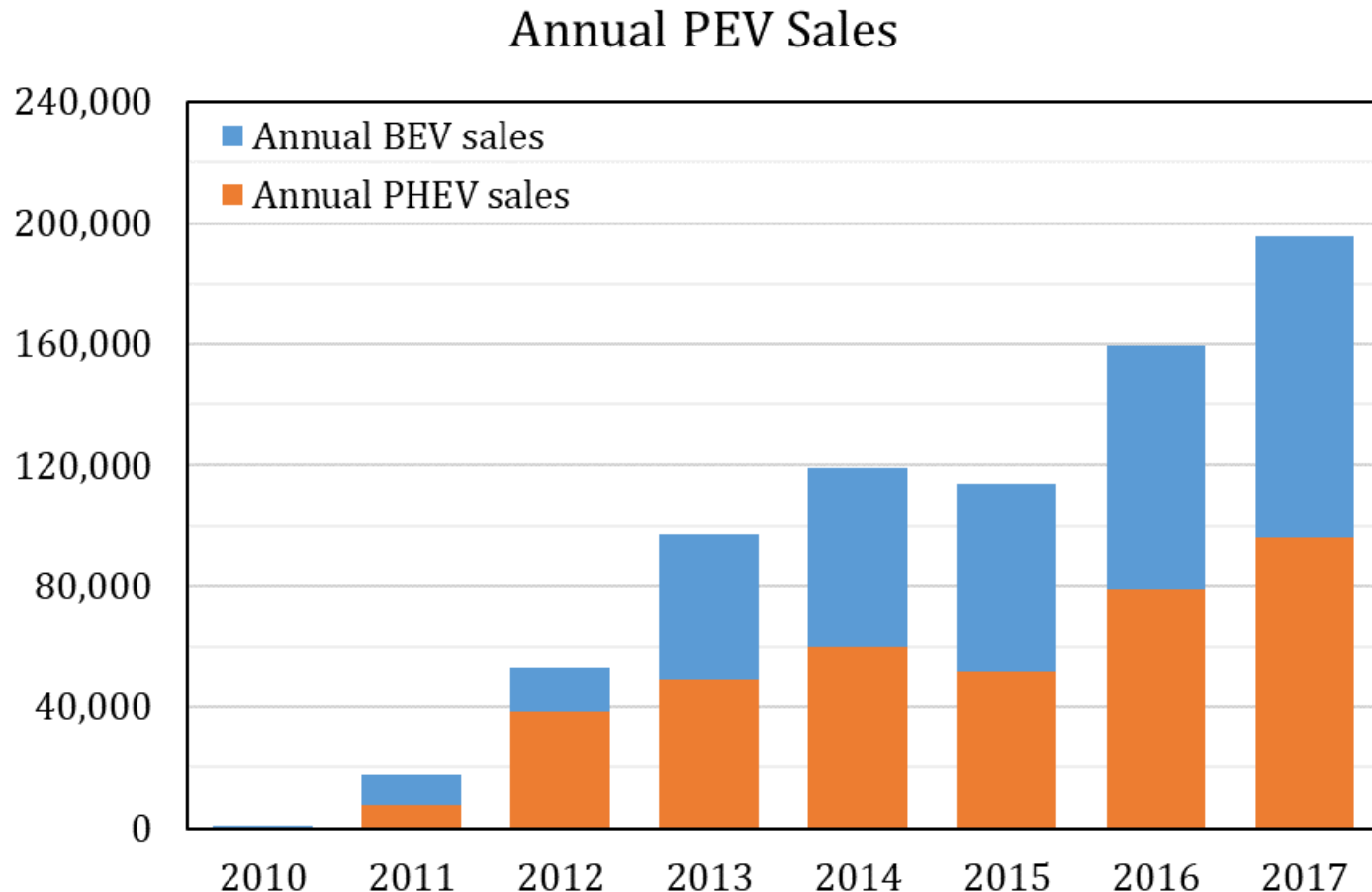


Light-duty vehicle sales shares
percent



PEV market

ANL: BEV and PHEV set sales records in 2017, with nearly 200,000 total sales in the United States



PEV market

EV-Sales: BAIC EC-Series top-selling EV model, Prius Prime #1 PHEV, and Tesla Model X top SUV worldwide



BAIC EC-Series: 78,079



Tesla Model S: 54,715



**Toyota Prius Prime:
50,830**



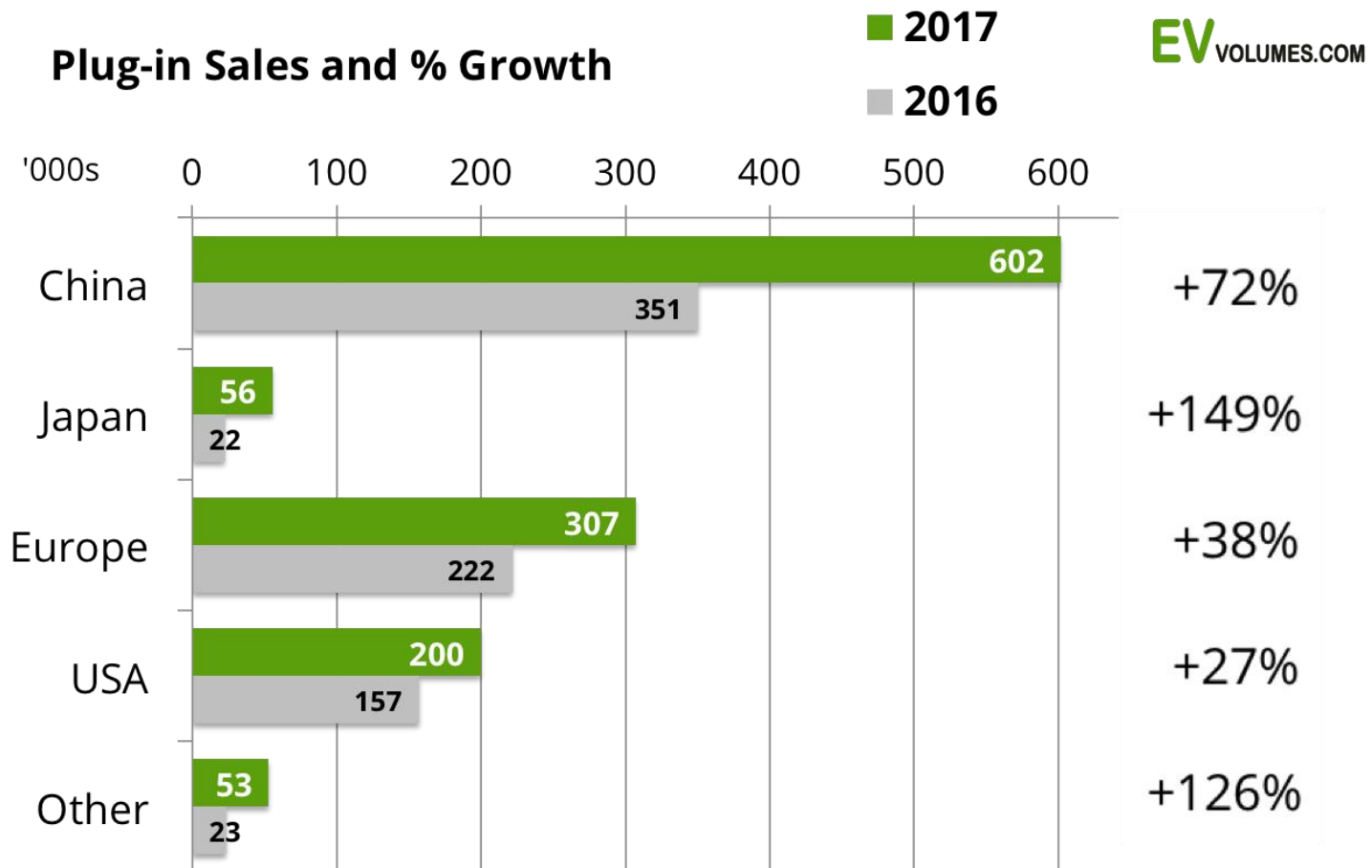
Nissan Leaf: 47,195



Tesla Model X: 46,535

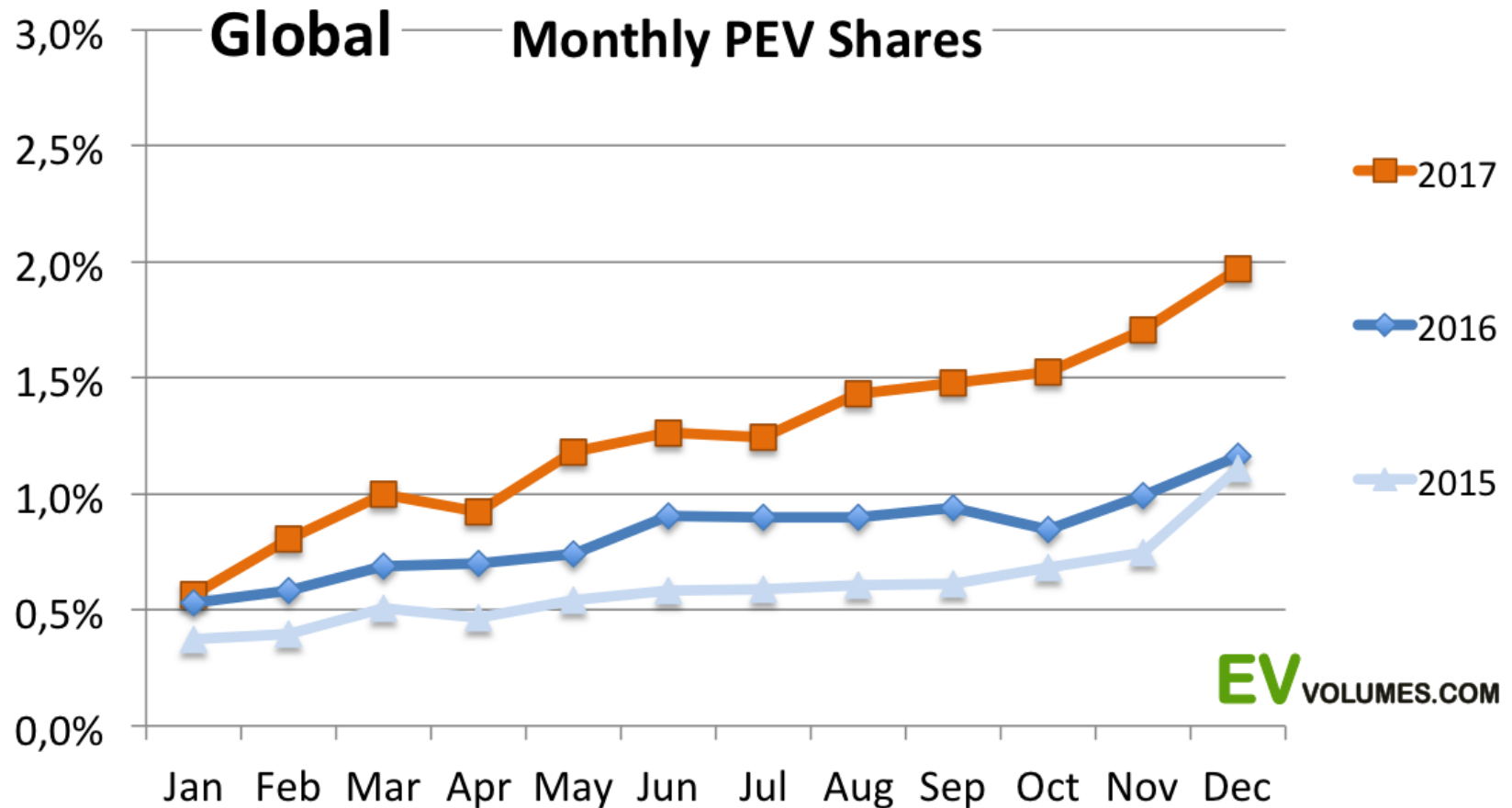
PEV market

EV-Volumes: China continues to be the world's top market for electric vehicles



PEV market

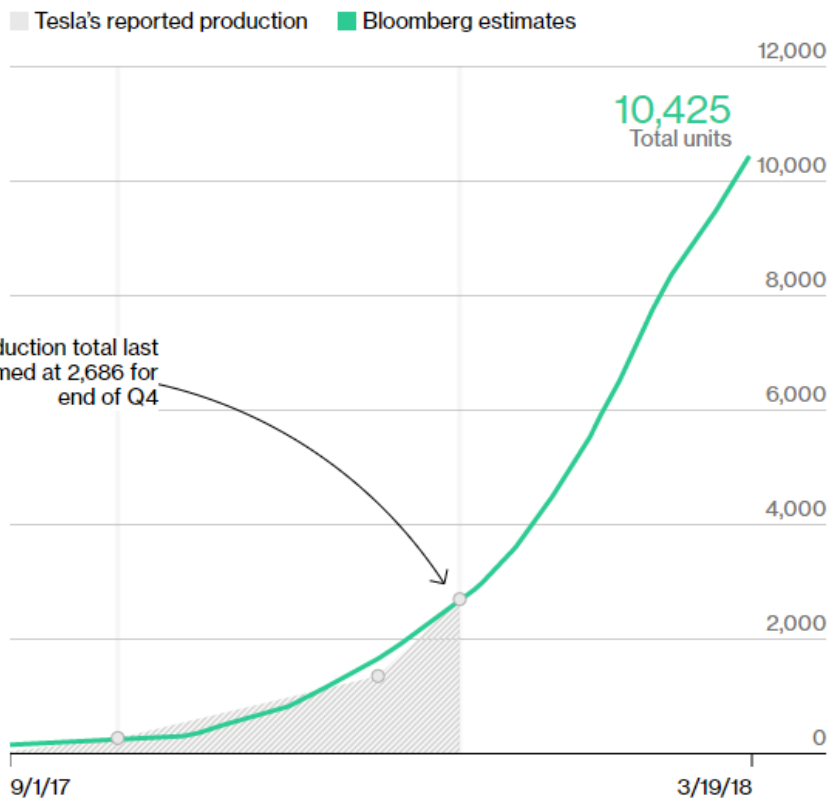
EV-Volumes: Nearly 2% of LDV sold worldwide were PEV in December 2017



PEV market

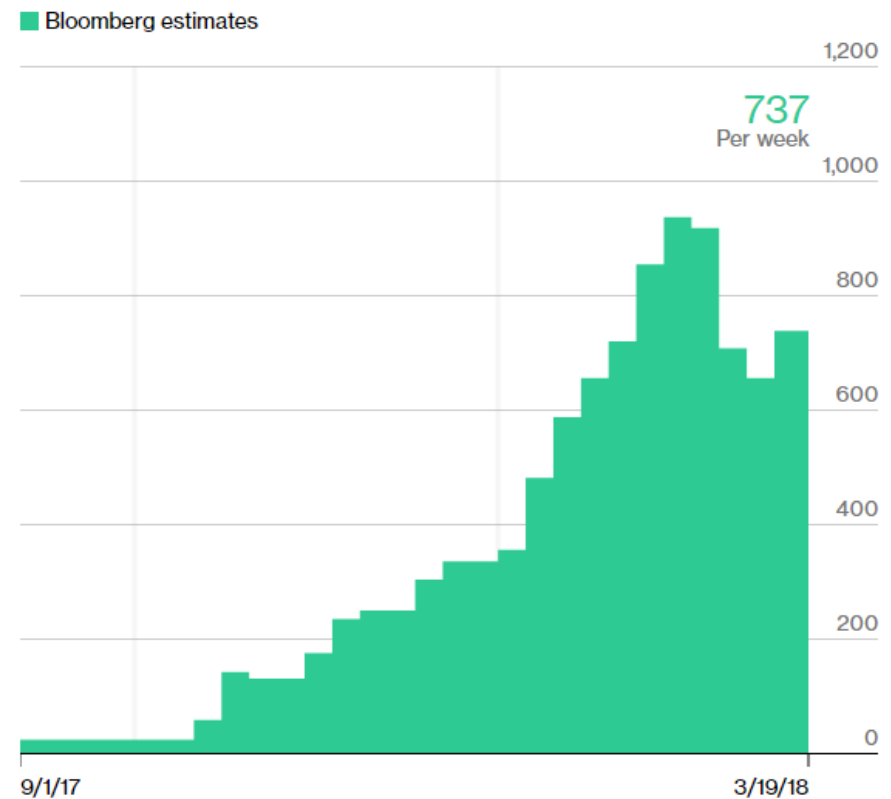
Bloomberg: Over 10,000 Tesla Model 3 have been produced

Total Model 3 Production



Source: Tesla, Bloomberg

Weekly Model 3 Production Rate

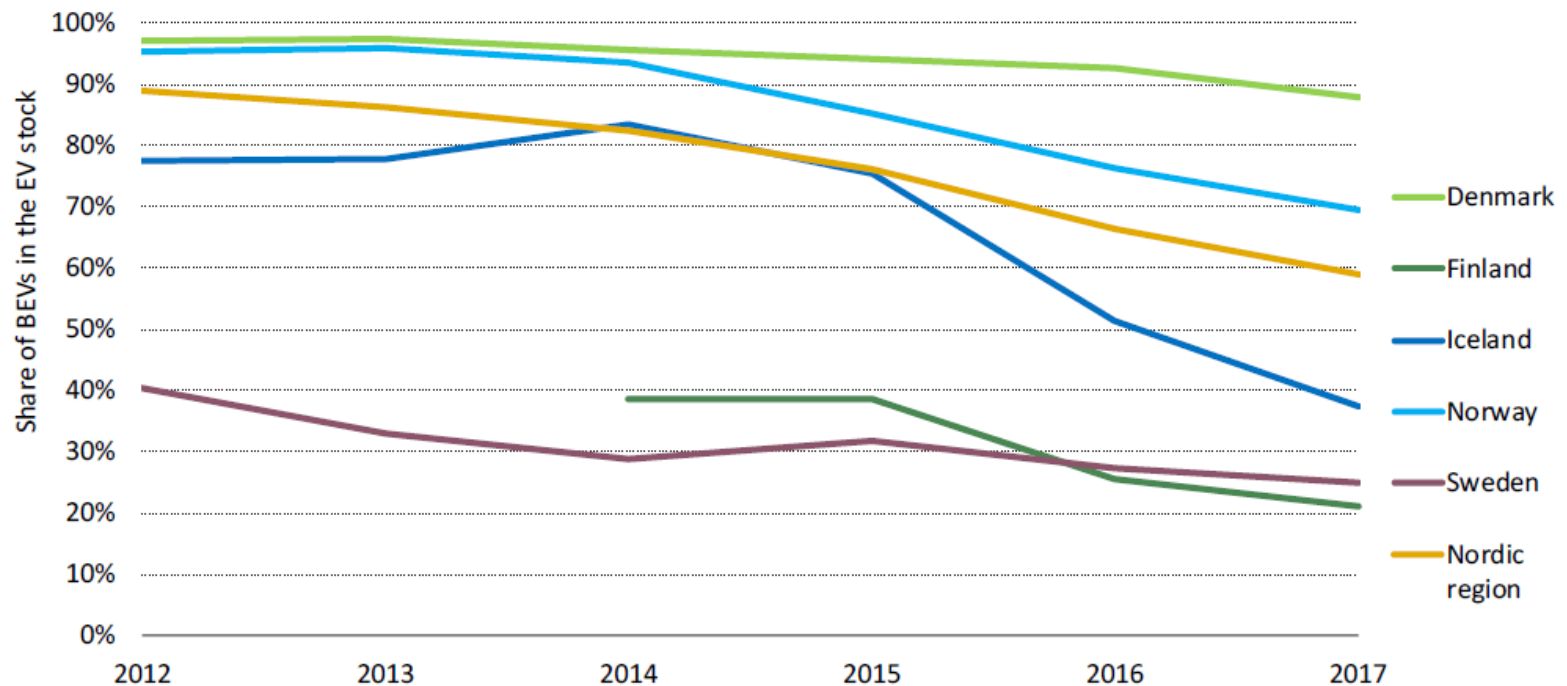


Source: Bloomberg

PEV market

IEA: The share of BEVs (relative to PHEVs) is declining in Nordic countries

Figure 2.3 • Share of BEVs in the electric car stock in the Nordic countries, 2012-17



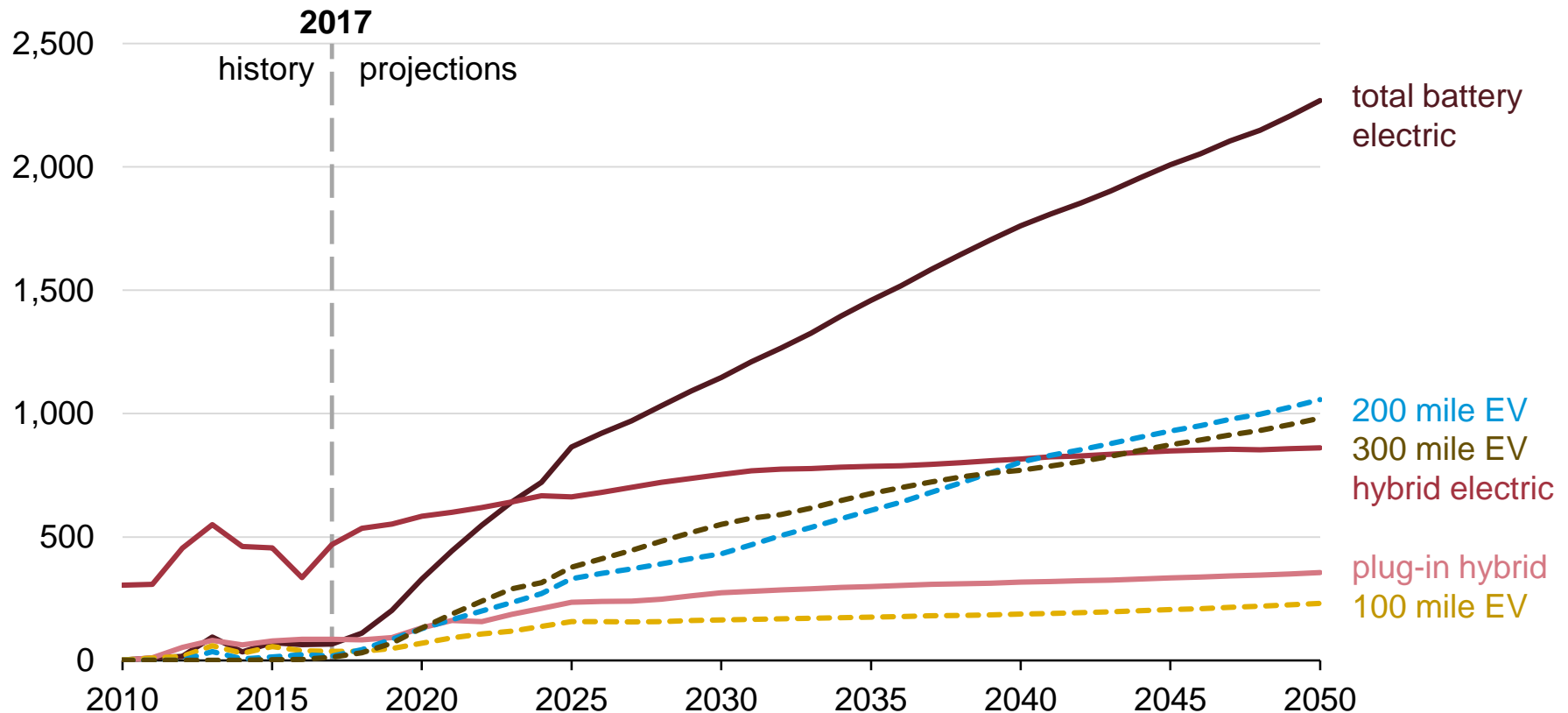
Sources: IEA analysis based on country submissions, complemented with ACEA (2017a, 2017b); Autoalan tiedotuskeskus (2017); EAFO (2017); EEA (2017); and Insero (2017, 2018).

Key point: On a regional basis, the share of BEVs in the electric car stock is declining.

PEV forecasts

EIA (AEO 2018): BEVs projected to reach 2 million sales in the United States by 2045

New vehicle sales of battery powered vehicles
thousands of vehicles

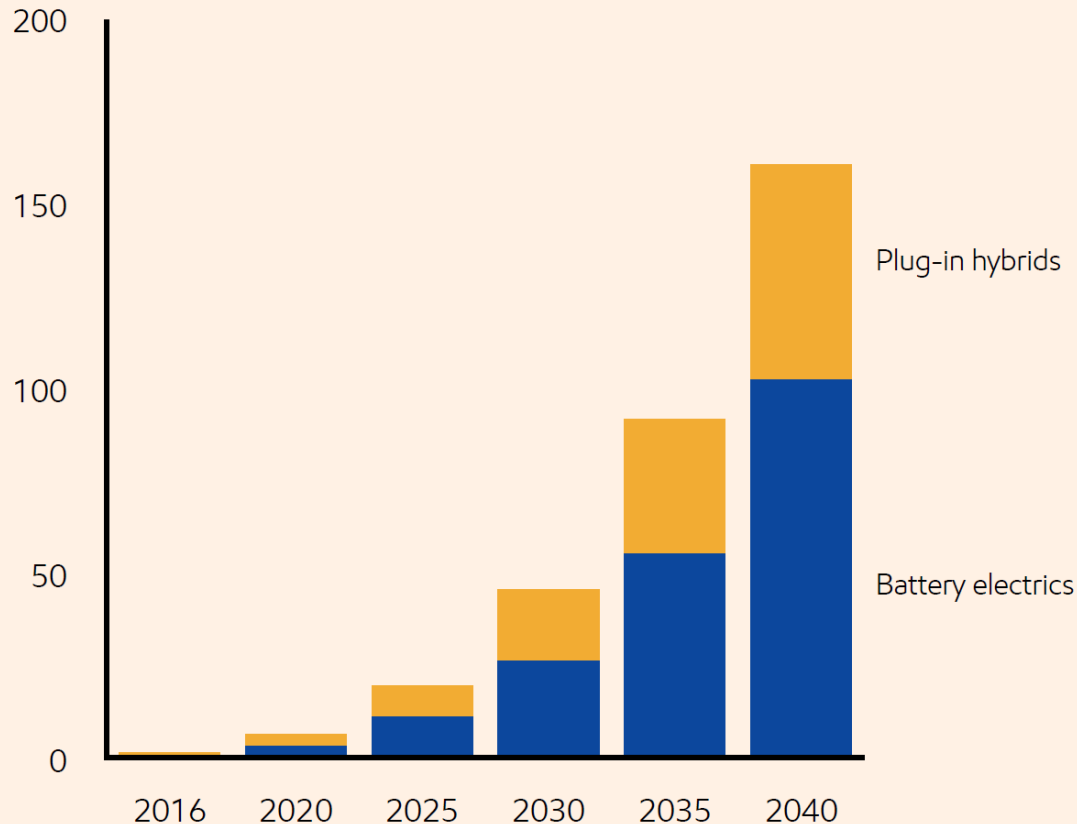


PEV forecasts

ExxonMobil: Worldwide PEVs to reach 150 million by 2040

Electric vehicles grow rapidly

Worldwide electric vehicle fleet – million cars

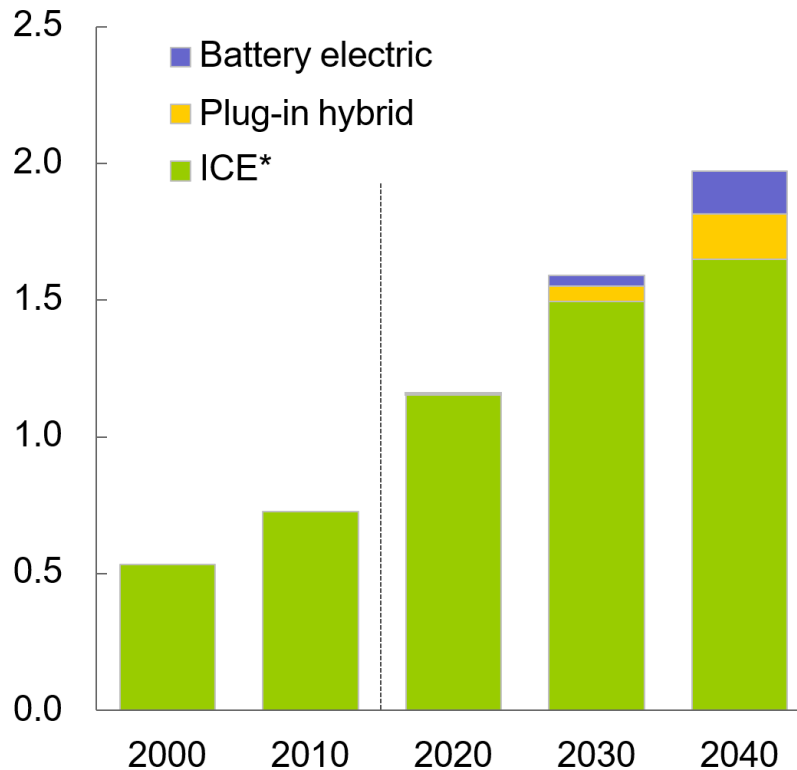


PEV forecasts

BP: PEVs will be over 15% of the worldwide fleet by 2040, more than twice last year's forecast

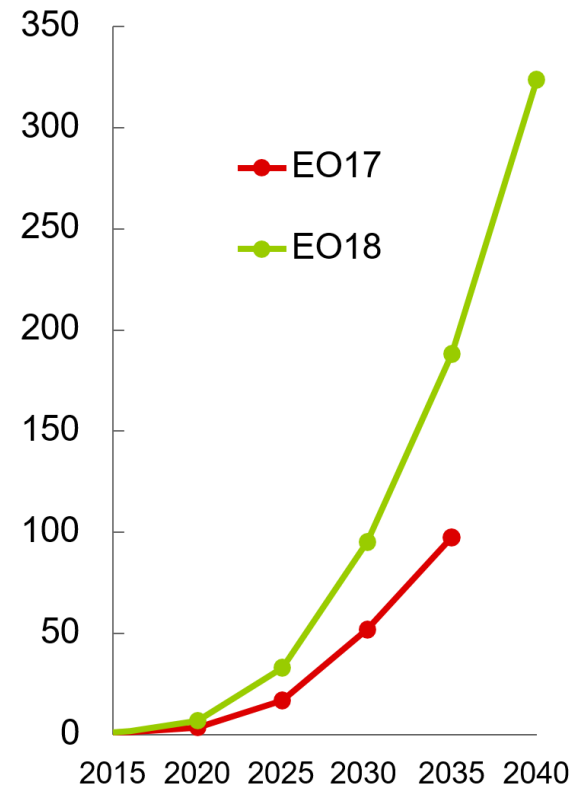
Passenger car parc by type

Billions of vehicles



Electric cars*

Millions of cars

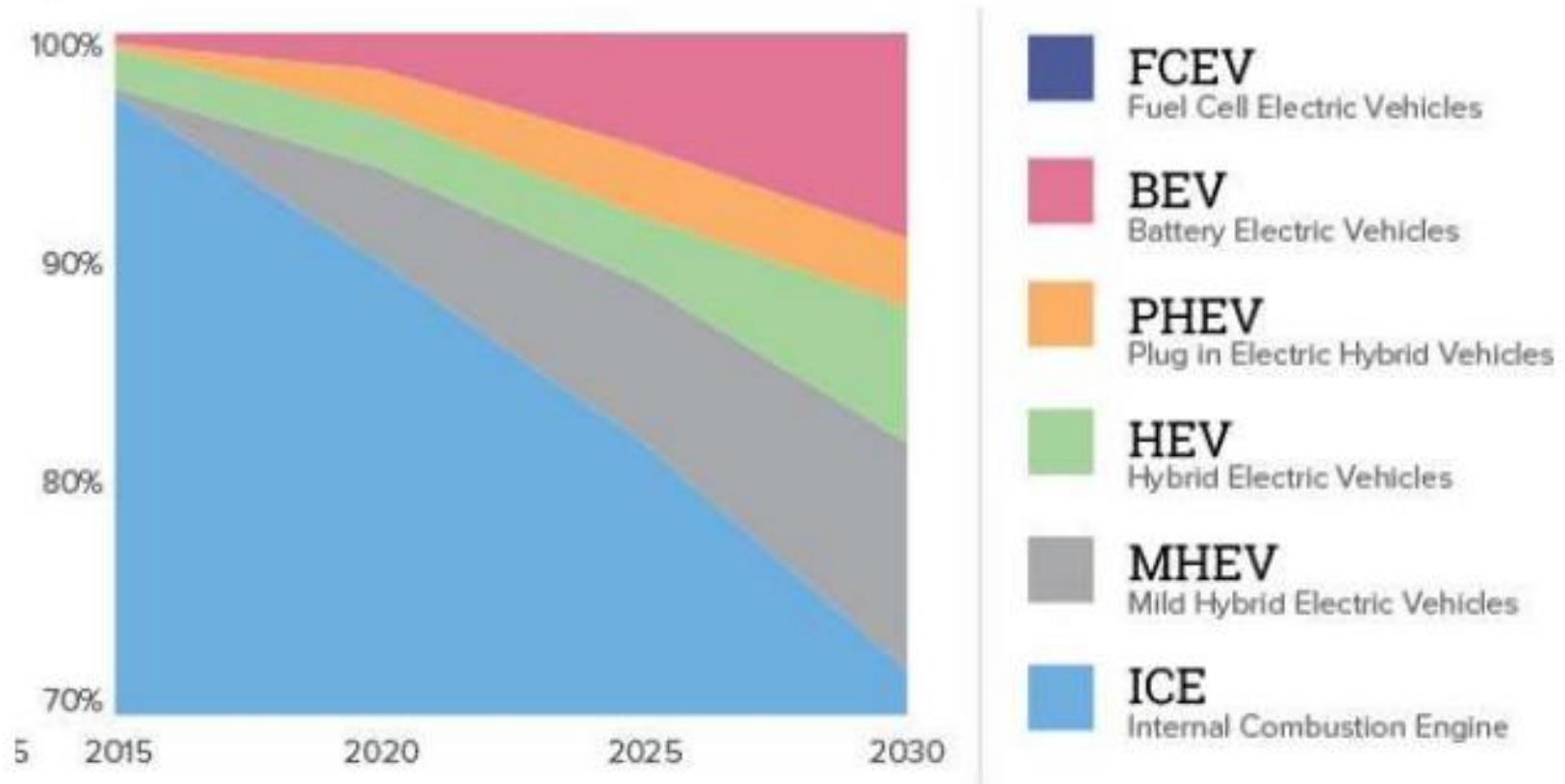


*Includes plug-in hybrids

PEV forecasts

CAR: 30% of new vehicles worldwide will have electrified powertrains in 2030

Figure 9: Global Powertrain Market Share 2015-2030



topics

energy markets

automotive markets

3 technologies studies

environmental studies

behavior & opinion surveys

policy & business studies

qar
outline

3 technologies studies

fuel economy

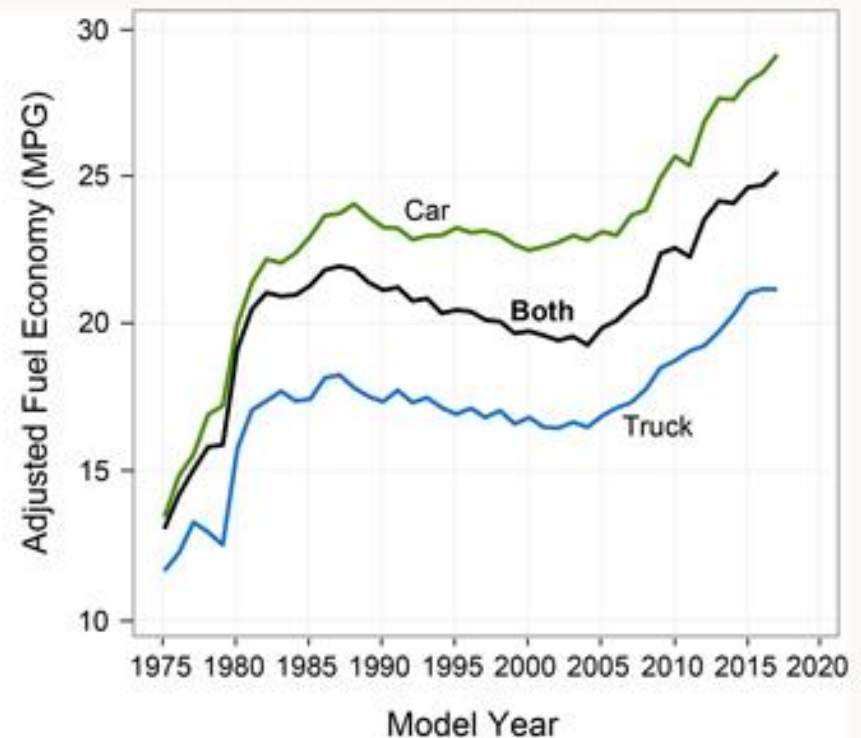
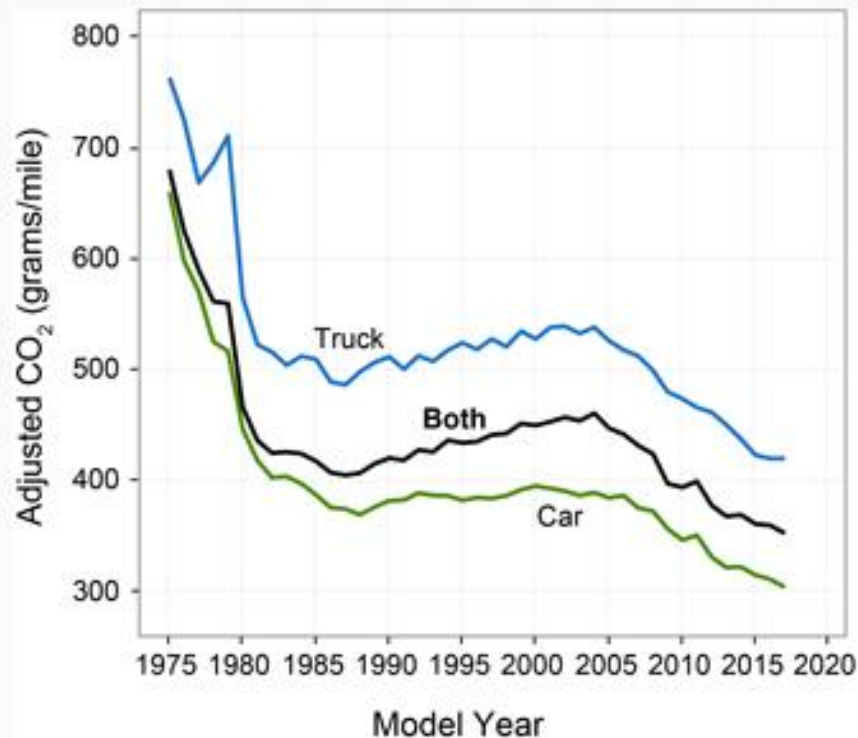
- > EPA: LDV fuel economy continues to improve to record levels
- > ANL: Average PEV in United States gets 100 MPGe

vehicle technologies

- > FOTW/EPA: Advanced technologies continue to be included in new cars as automakers improve fuel economy

fuel economy

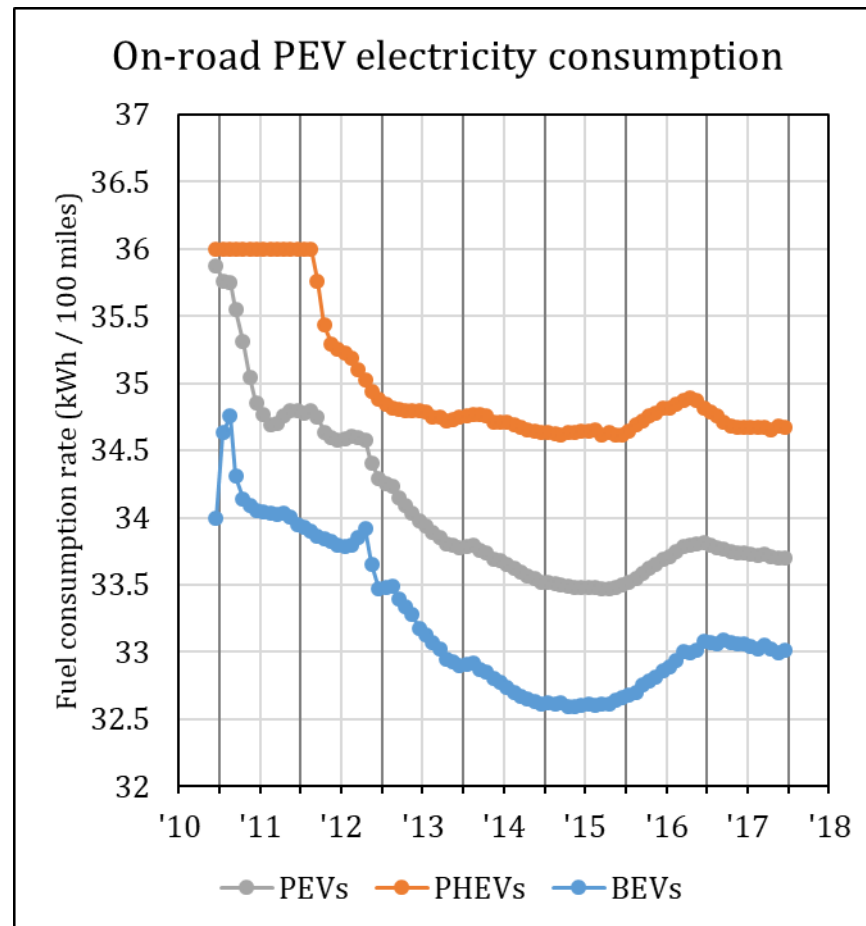
EPA: LDV fuel economy continues to improve to record levels



¹Adjusted CO₂ and fuel economy values reflect real world performance and are not comparable to automaker standards compliance levels. Adjusted CO₂ values are, on average, about 25% higher than the unadjusted, laboratory CO₂ values that form the starting point for GHG standards compliance, and adjusted fuel economy values are about 20% lower, on average, than unadjusted fuel economy values that form the starting point for CAFE standards compliance.

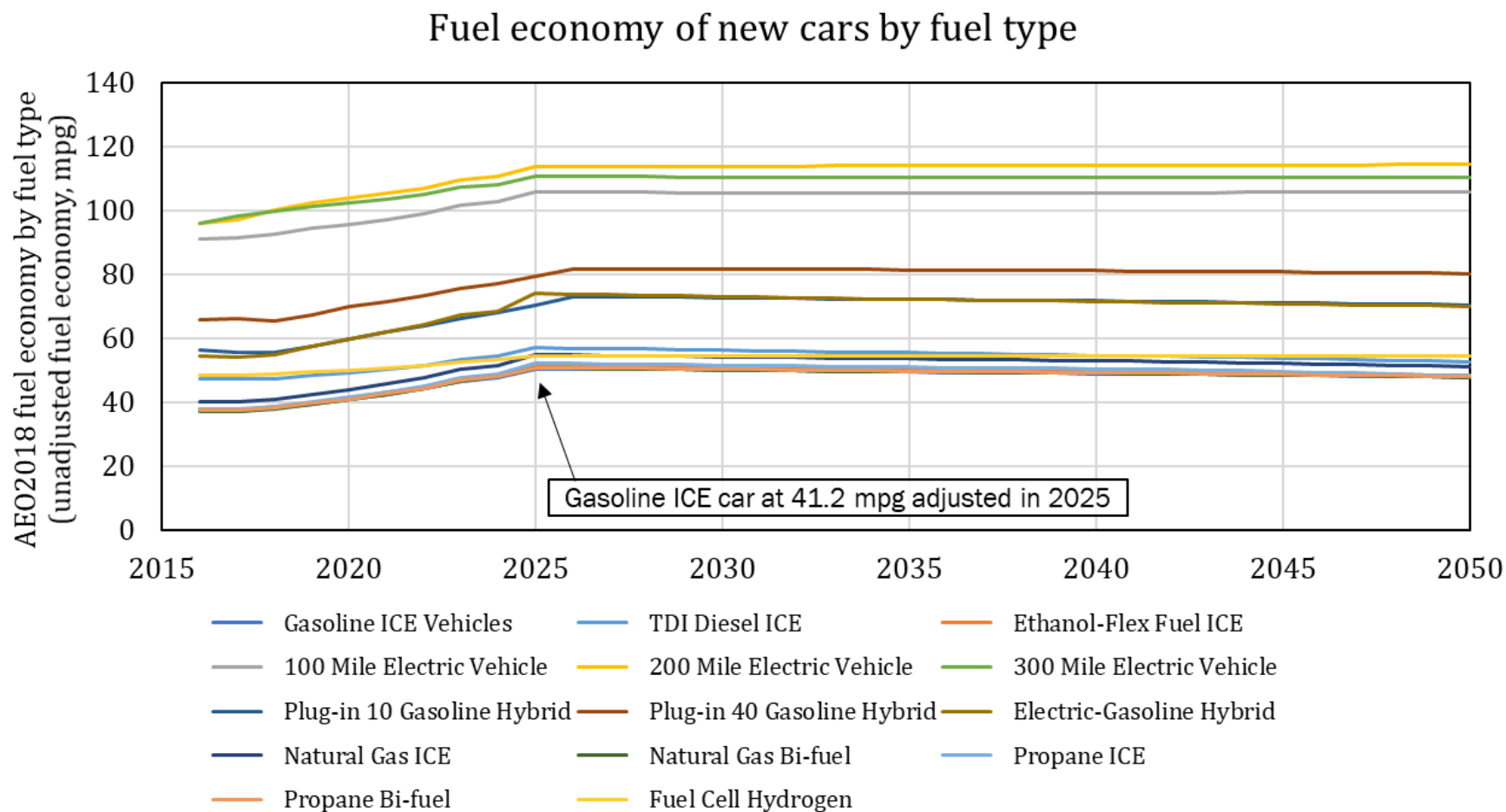
fuel economy

ANL: Average energy consumption of BEVs in the U.S. is approximately 0.33 kWh/mile, PHEVs slightly higher



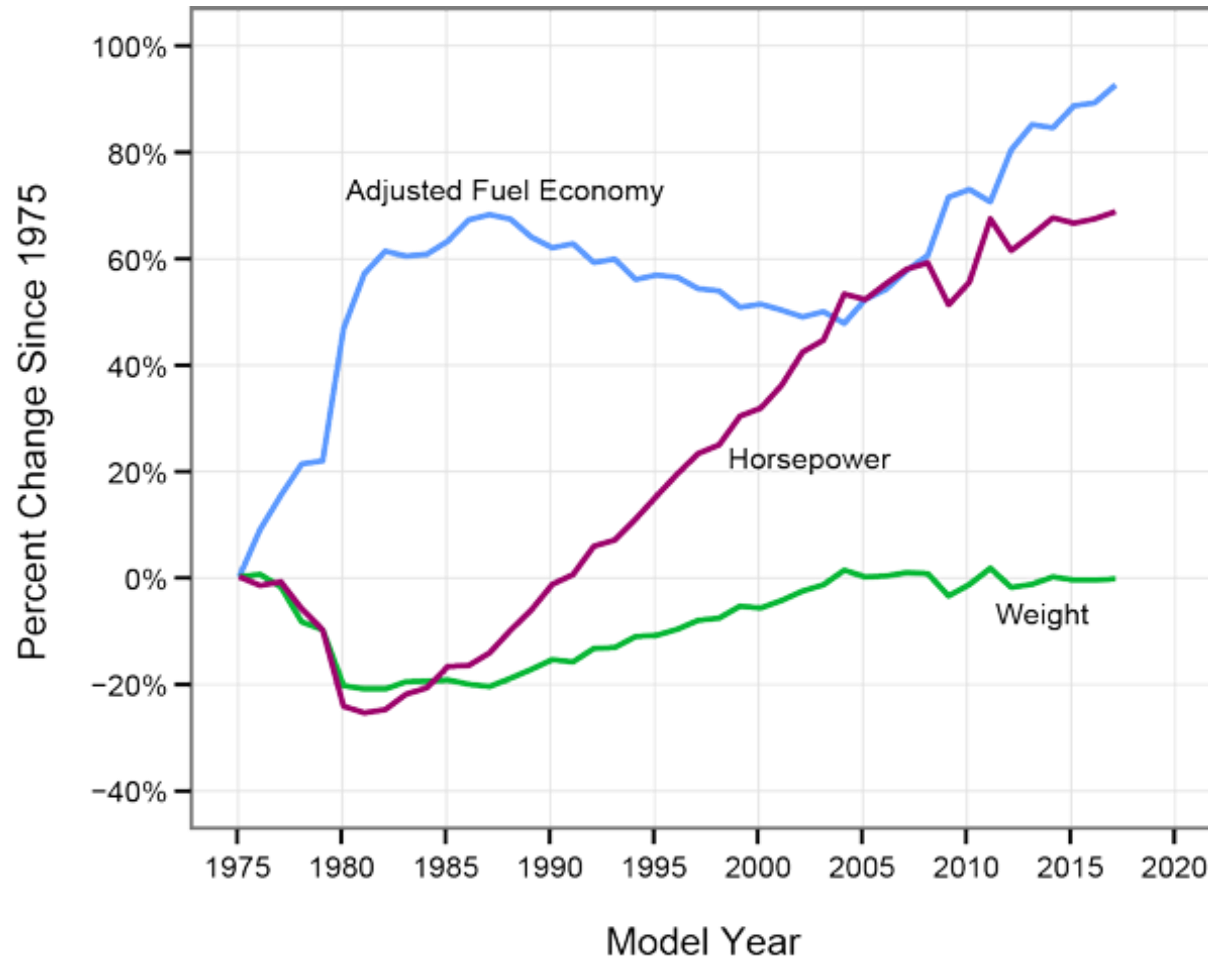
fuel economy

EIA (AEO 2018): Fuel economy for all drivetrains expected to increase quickly through 2025



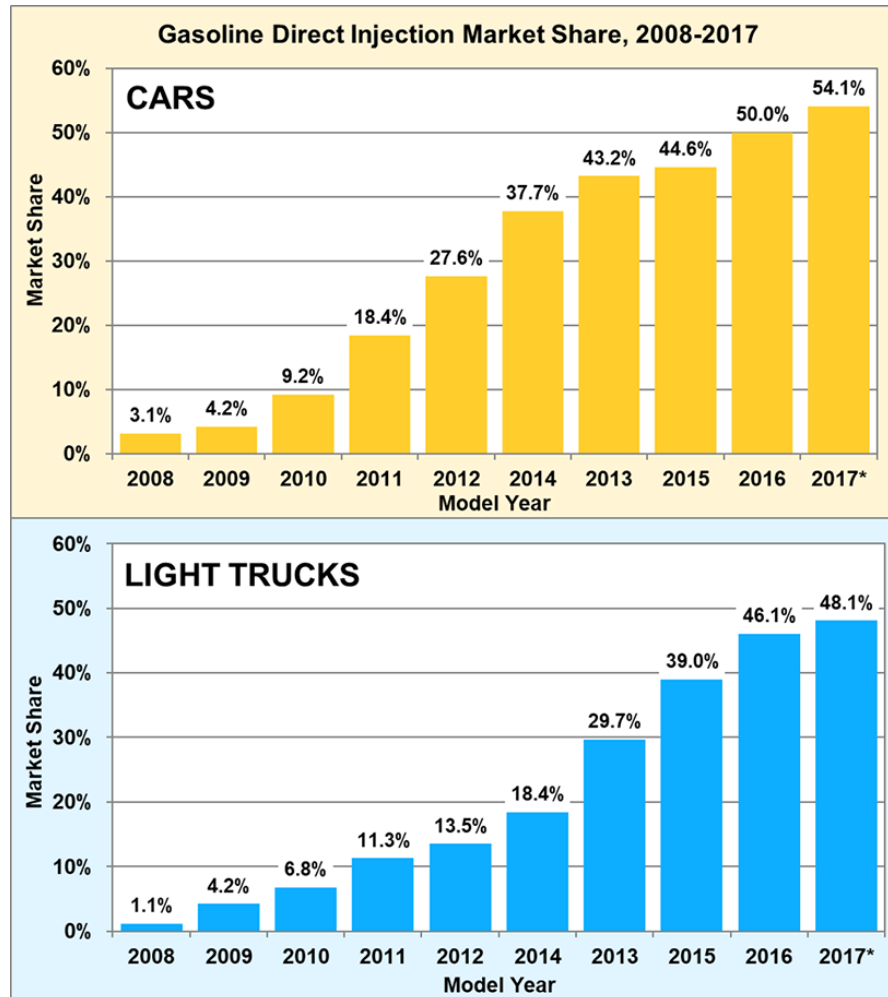
vehicle technologies

EPA: LDV fuel economy and horsepower are simultaneously at record-high levels



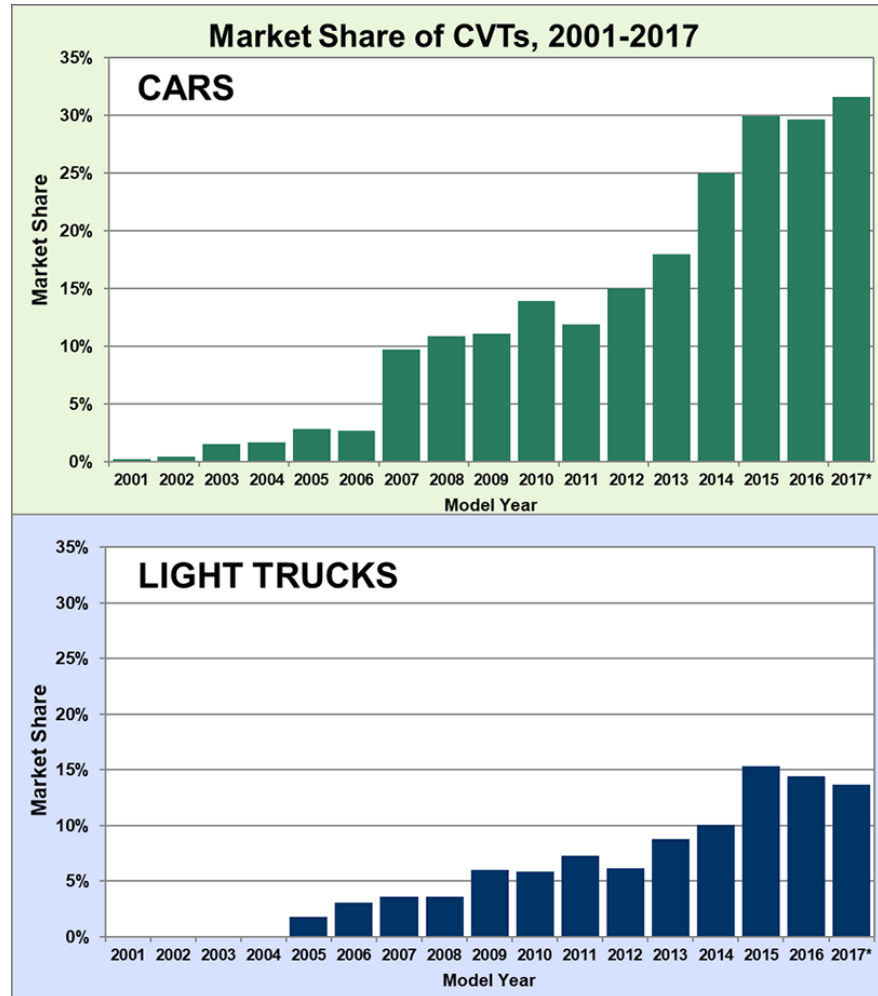
vehicle technologies

FOTW: About half of new cars and light trucks have gasoline direct injection



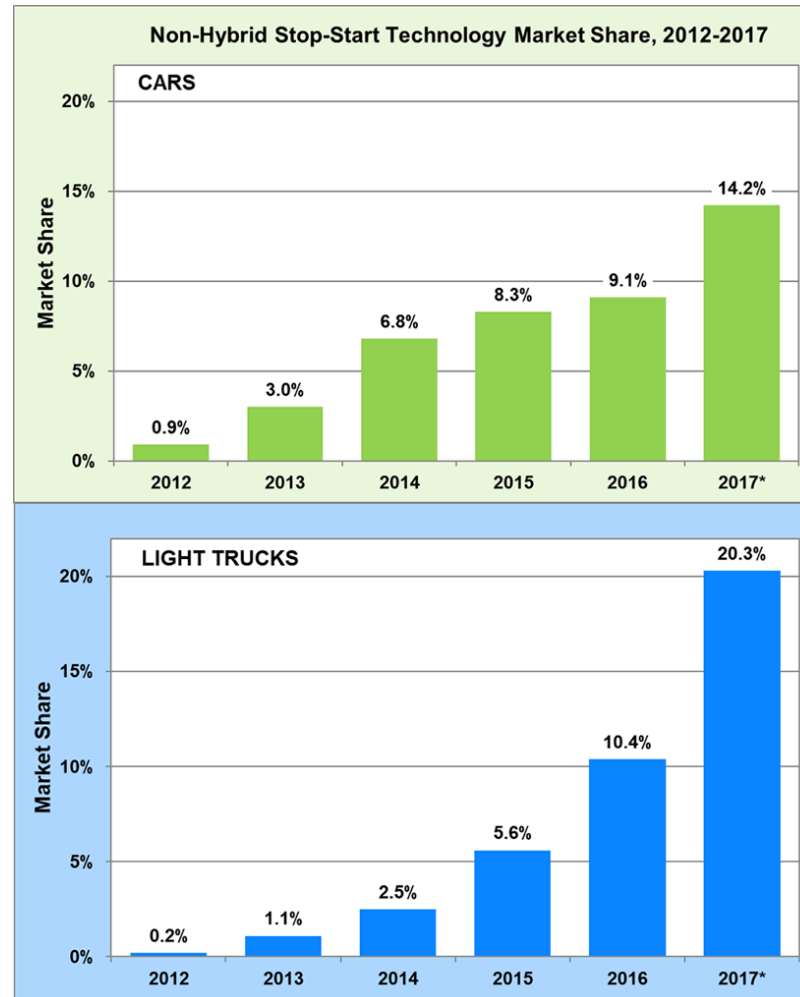
vehicle technologies

FOTW: Over 30% of MY2017 cars have continuously variable transmissions



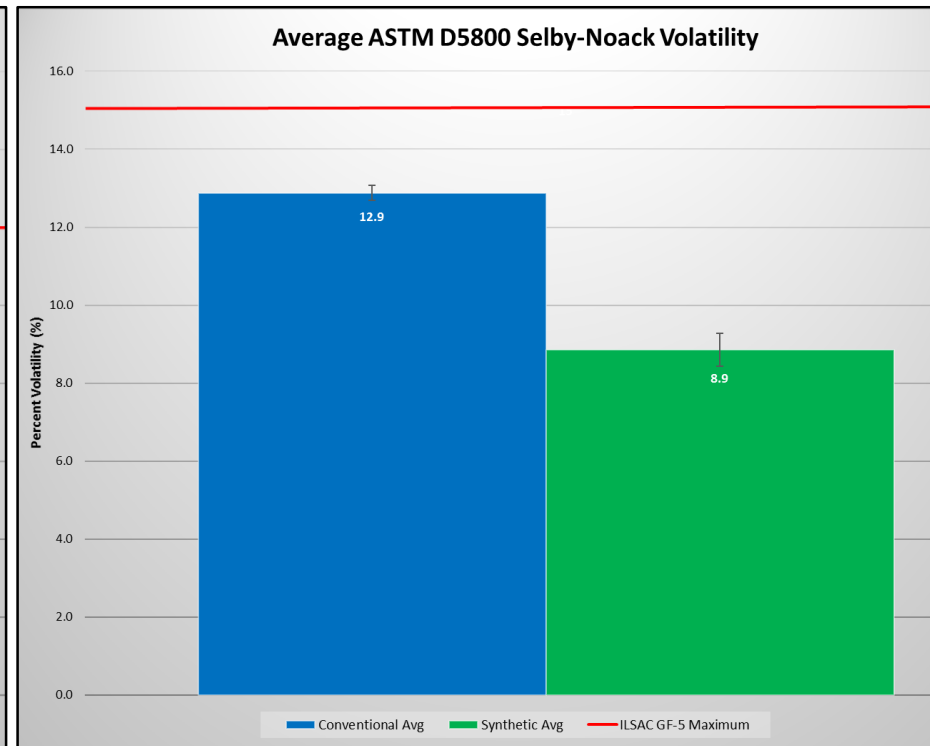
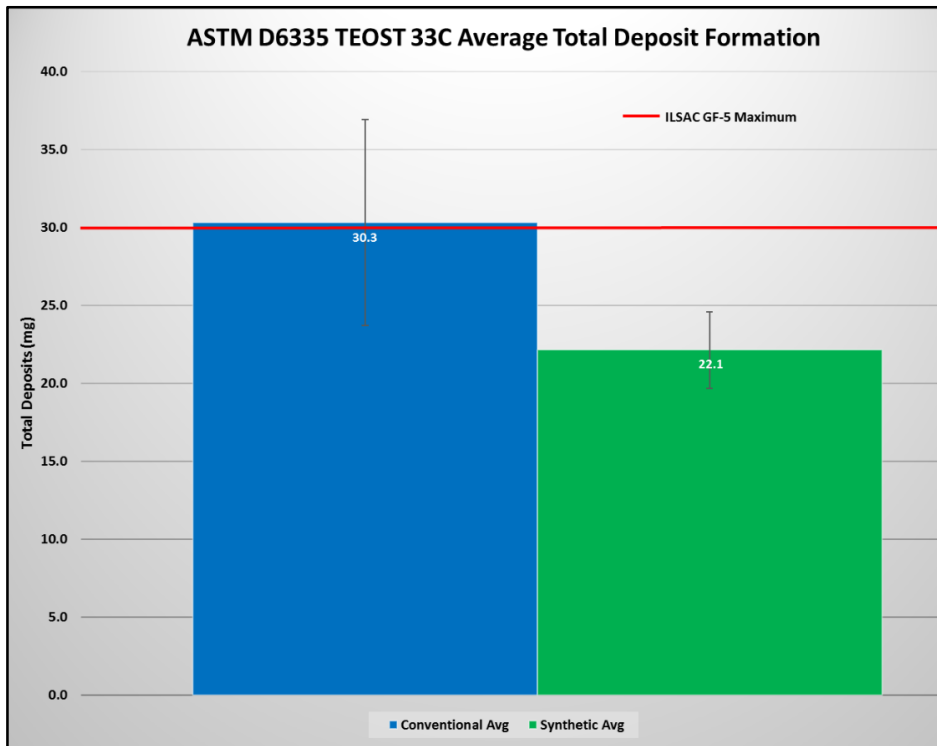
vehicle technologies

FOTW: Non-hybrid stop-start systems doubled in new light trucks from 2016 to 2017



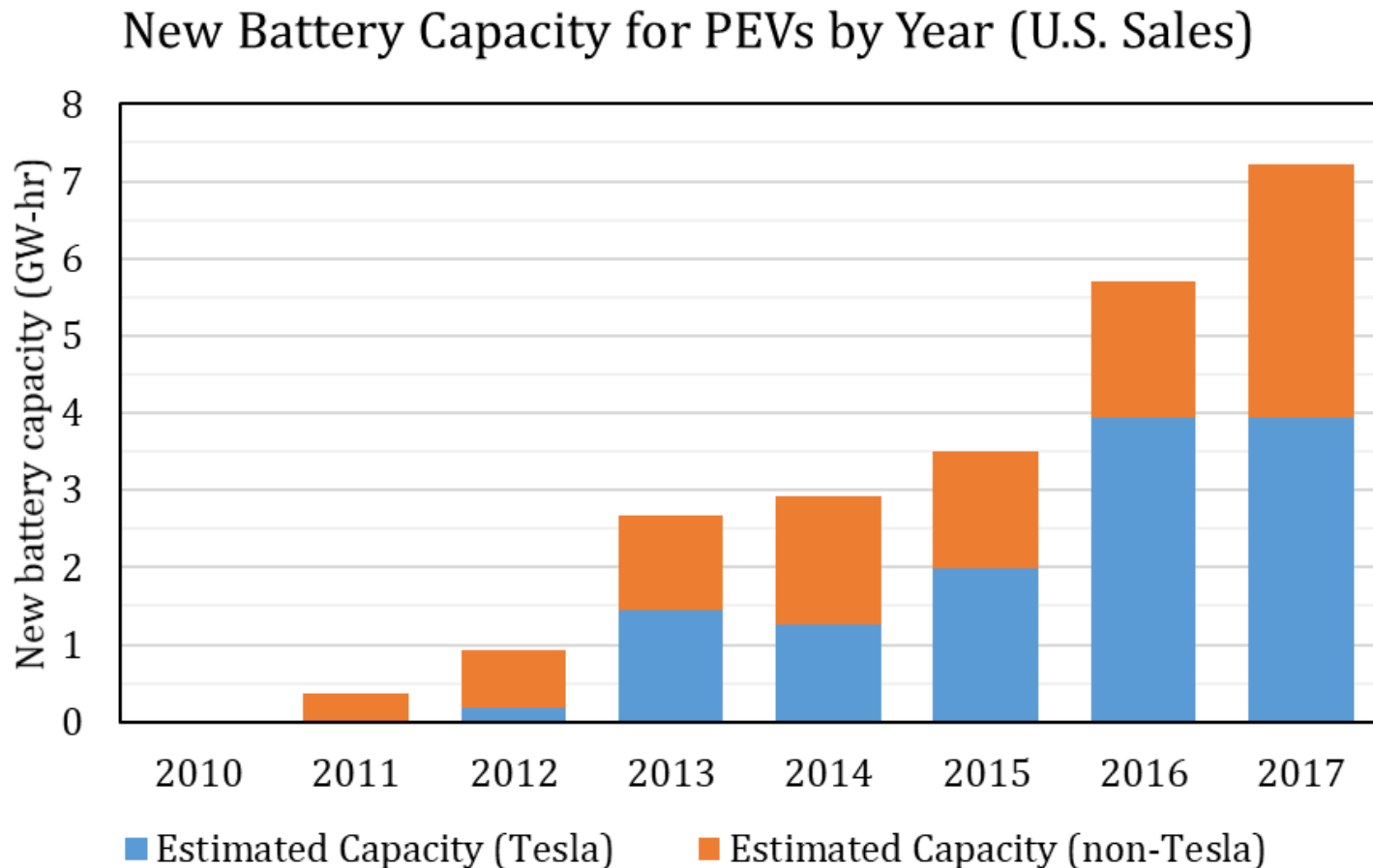
vehicle technologies

AAA: Synthetic oils perform better than conventional, with lower deposit formation (particularly in extreme conditions) and lower volatility



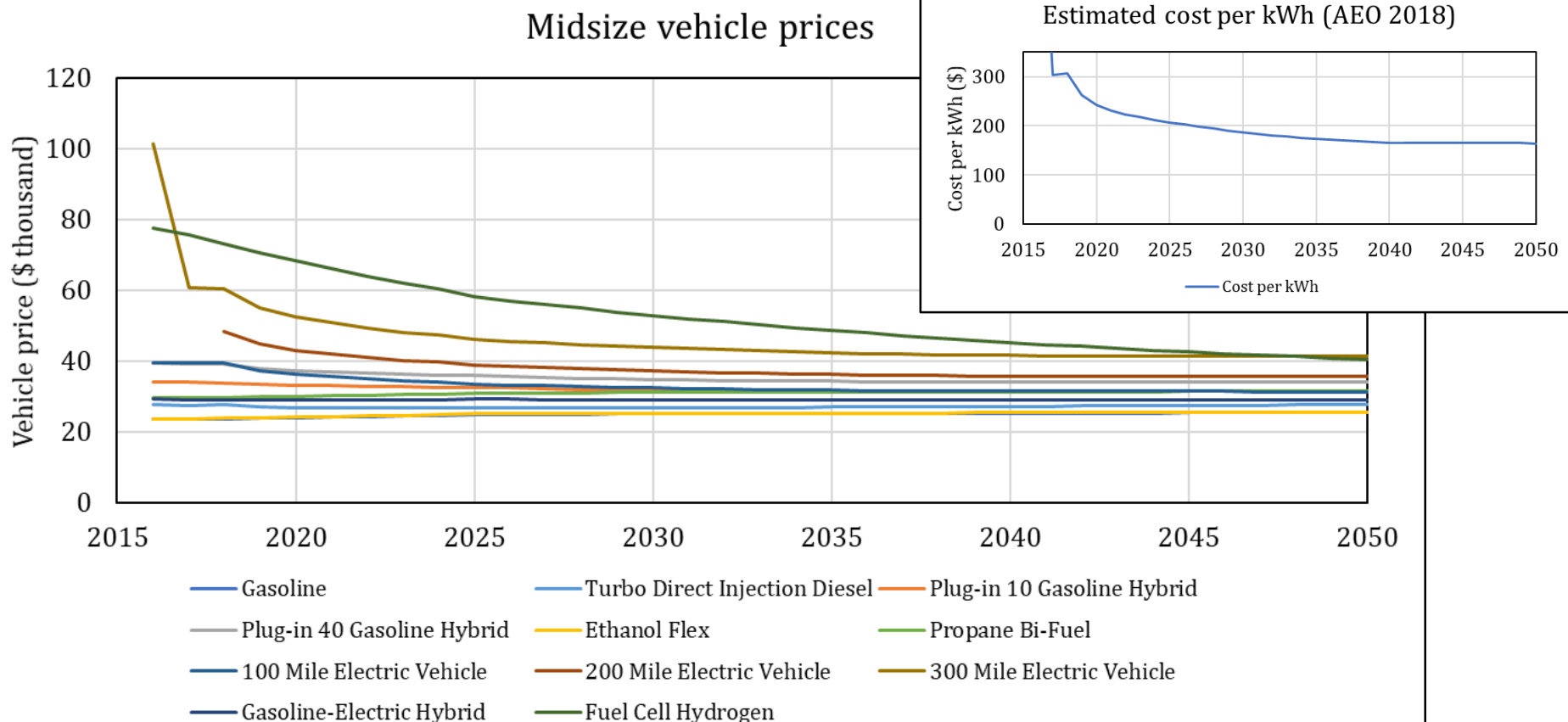
battery manufacturing

ANL: Over 23 GWh of Li-ion battery storage is on the road in PEVs in the United States



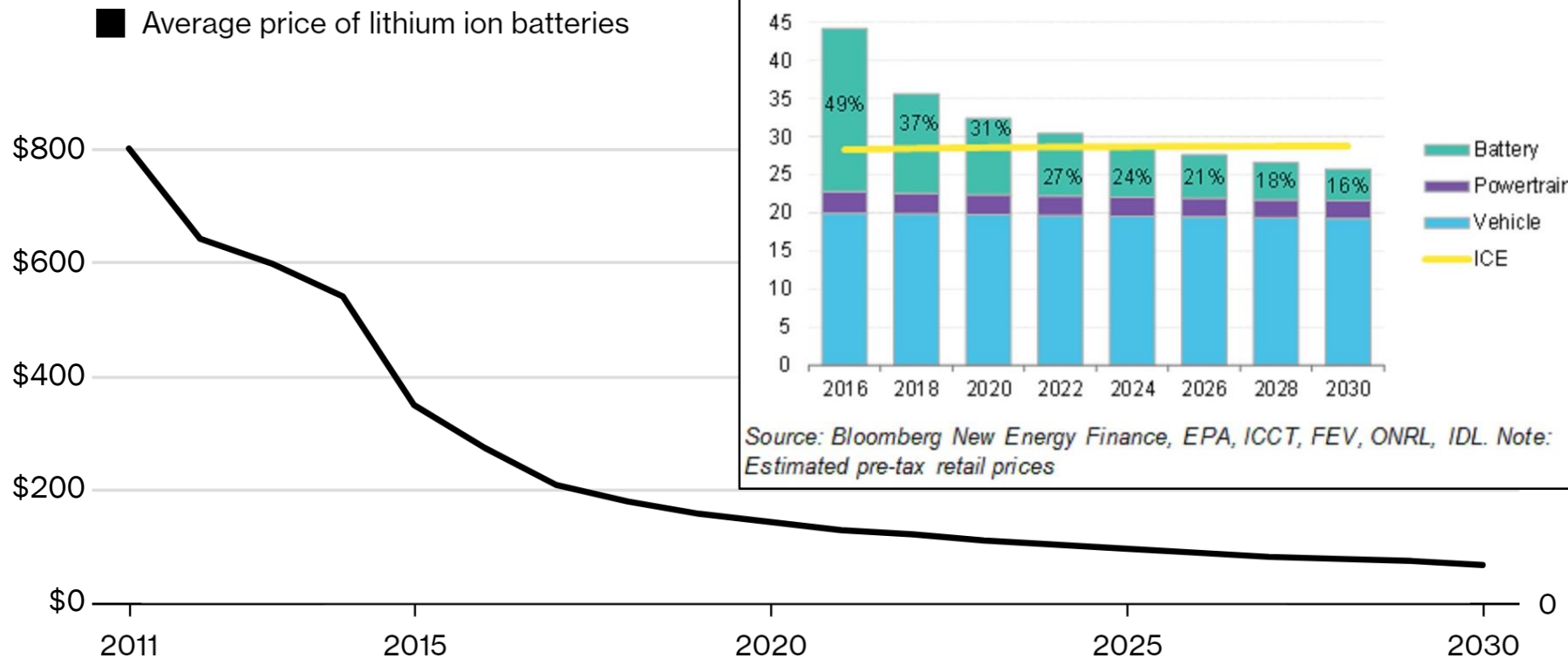
battery manufacturing

EIA (AEO 2018): Prices for alternative fuel vehicles will not come near ICE prices through 2050



battery manufacturing

BNEF: BEVs (at \$104/kWh) will reach cost parity with ICE vehicles by 2024

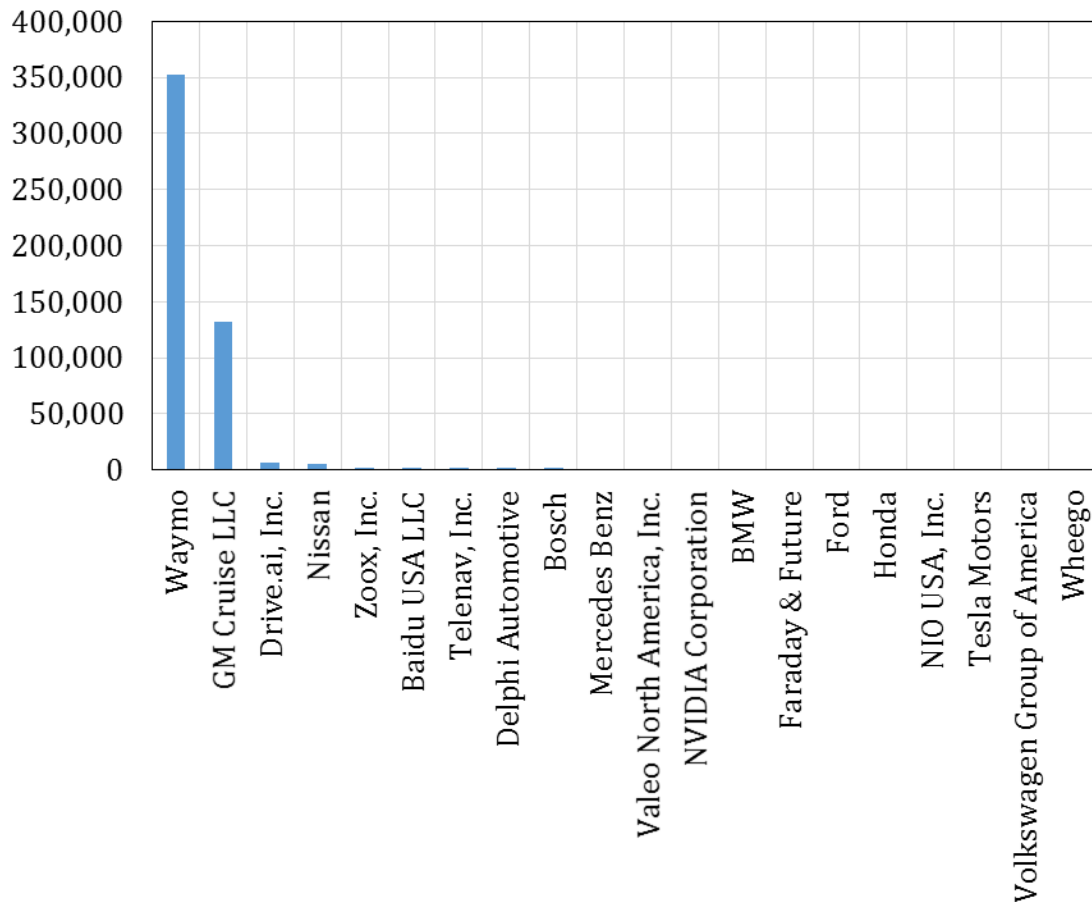


Source: Bloomberg New Energy Finance

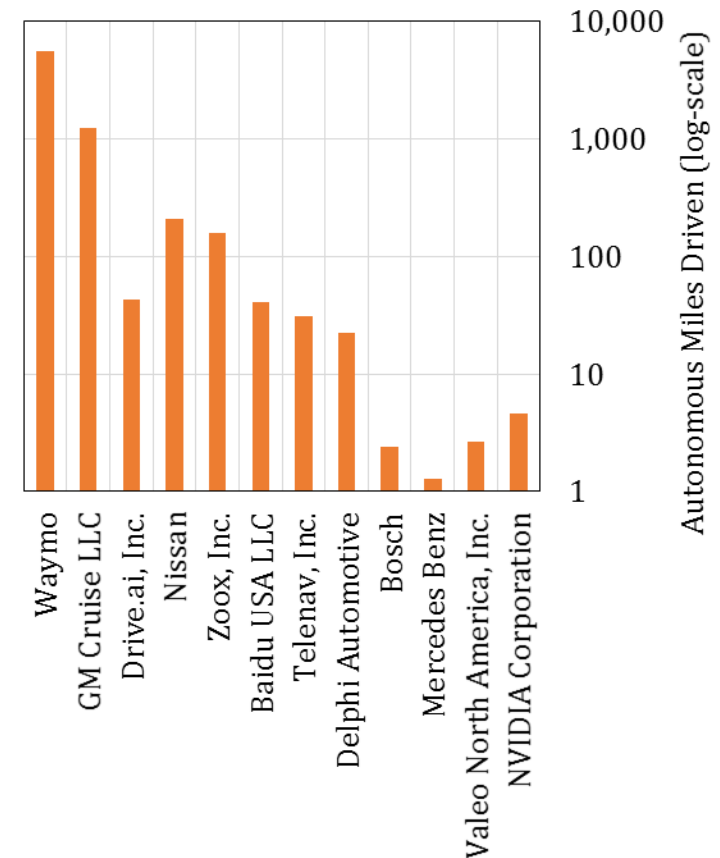
CAV technologies

CA DMV: Waymo drove 5,000 automated miles per disengagement in 2017, only GM Cruise over 200

Autonomous Miles Driven in California (2017)



Autonomous Miles Driven per Vehicle Disengagement (2017)



topics

energy markets

automotive markets

technologies studies

4 environmental studies

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qar
outline

4 environmental studies

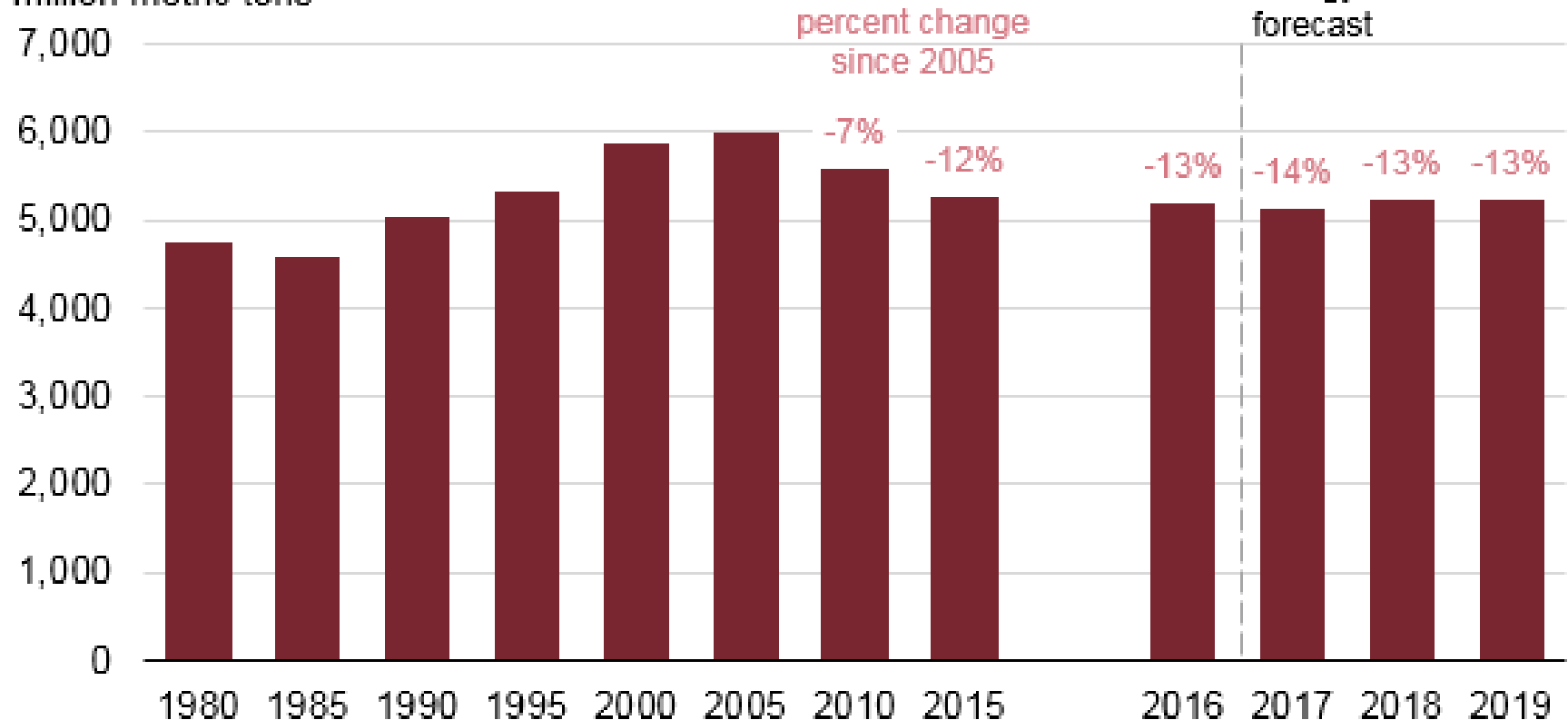
emissions

- > EIA: U.S. energy-related CO2 emissions flat since 2015, expected to remain at this level through 2019
- > EU: Real GDP has grown while GHG emissions have decreased in Europe
- > Ford/UM: CAVs technologies can improve operations, but increase emissions for vehicle manufacturing
- > EPA/NYT: Glider trucks can emit far more pollution than conventional tractors

emissions

EIA: Energy-related CO₂ emissions have been flat since 2015; expected to stay at this level through 2019

U.S. energy-related carbon dioxide emissions (1980-2019)
million metric tons



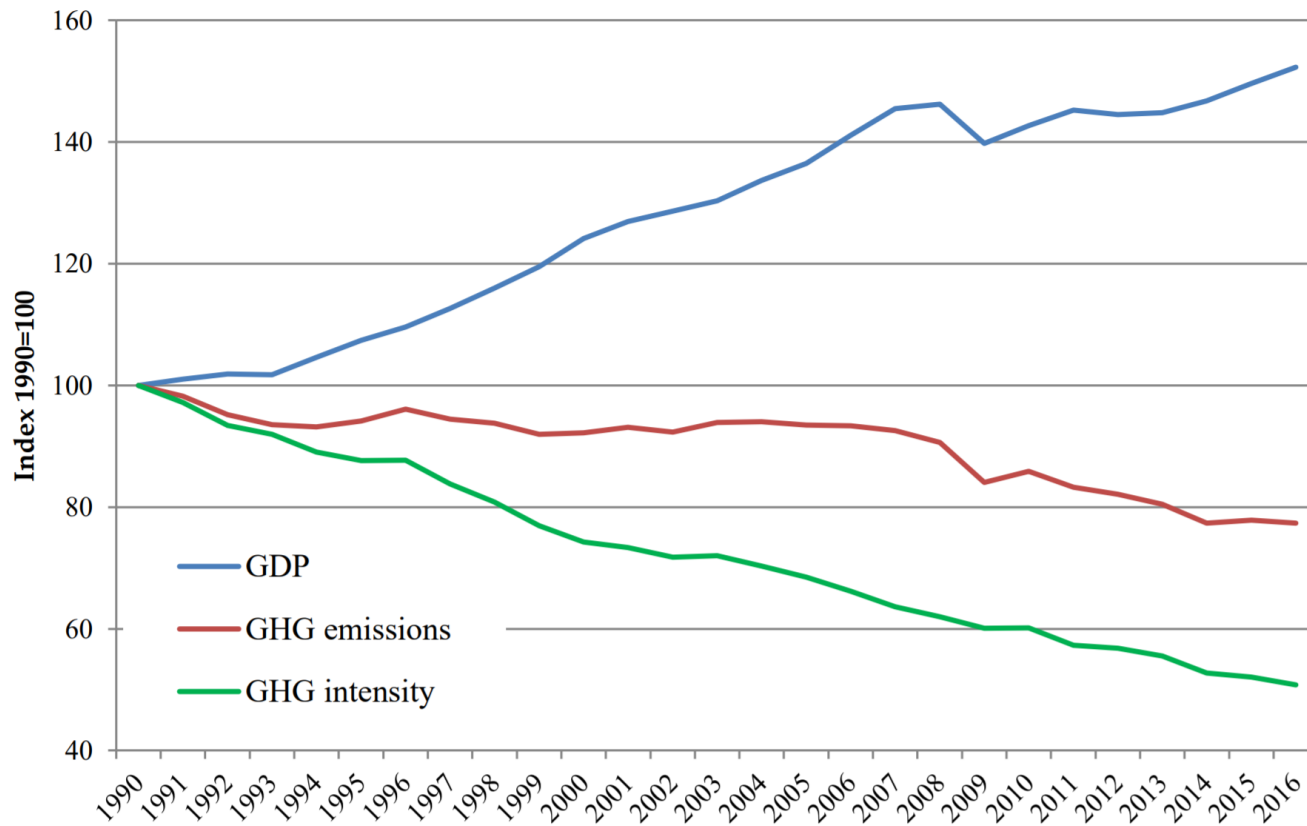
Short-Term
Energy Outlook
forecast



emissions

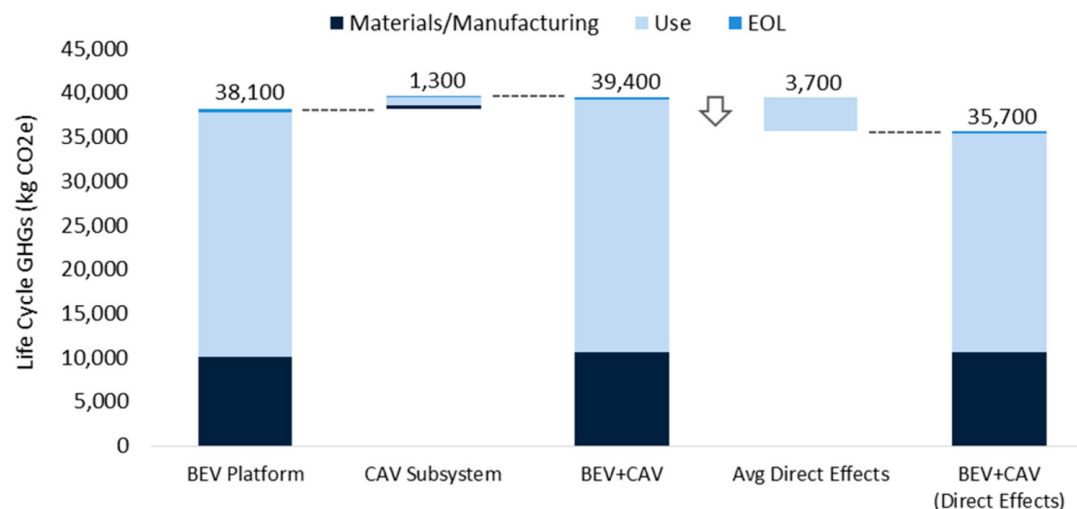
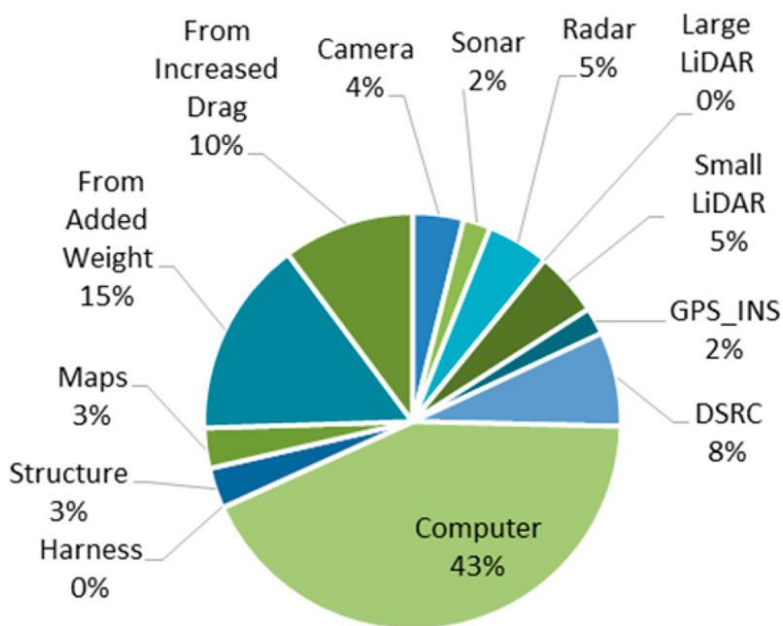
EU: Real GDP has grown in Europe while GHG emissions and carbon intensity have decreased

Figure 2: Change in real GDP, GHG emissions and GHG emission intensity in the EU, 1990-2016



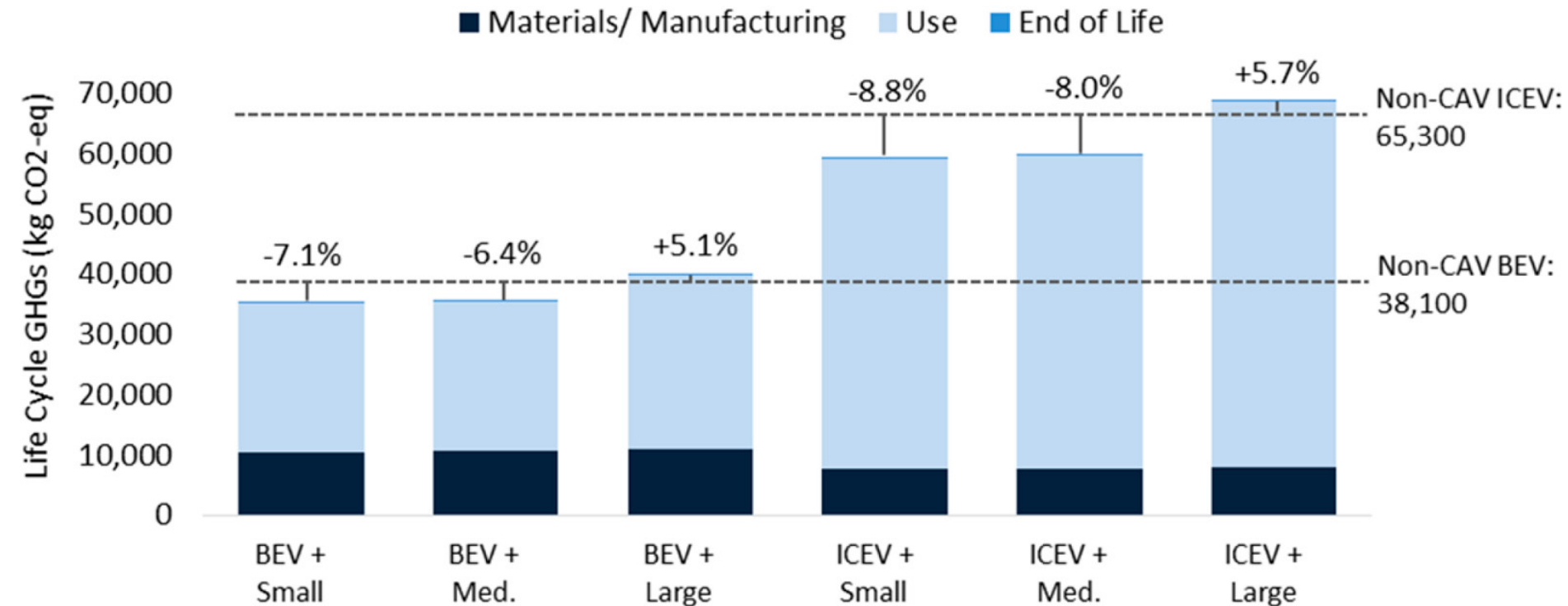
CAVs technology

Ford/UM: Computing and sensing equipment in vehicles can increase total GHGs/mile for CAVs



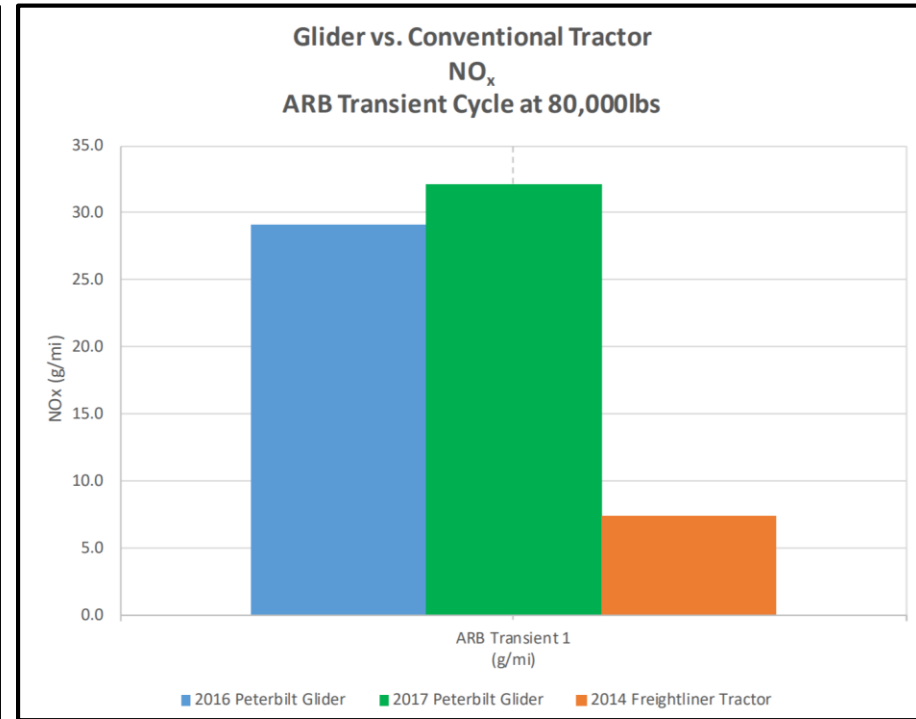
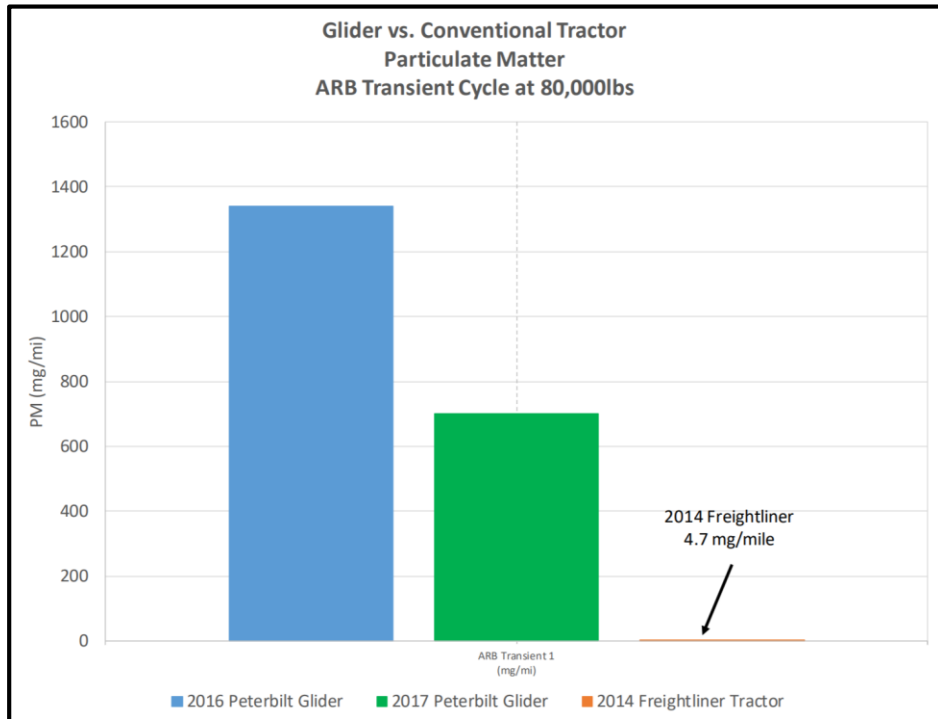
CAVs technology

Ford/UM: Total GHGs from CAVs can grow or shrink relative to baseline, depending on size of AV system



freight emissions

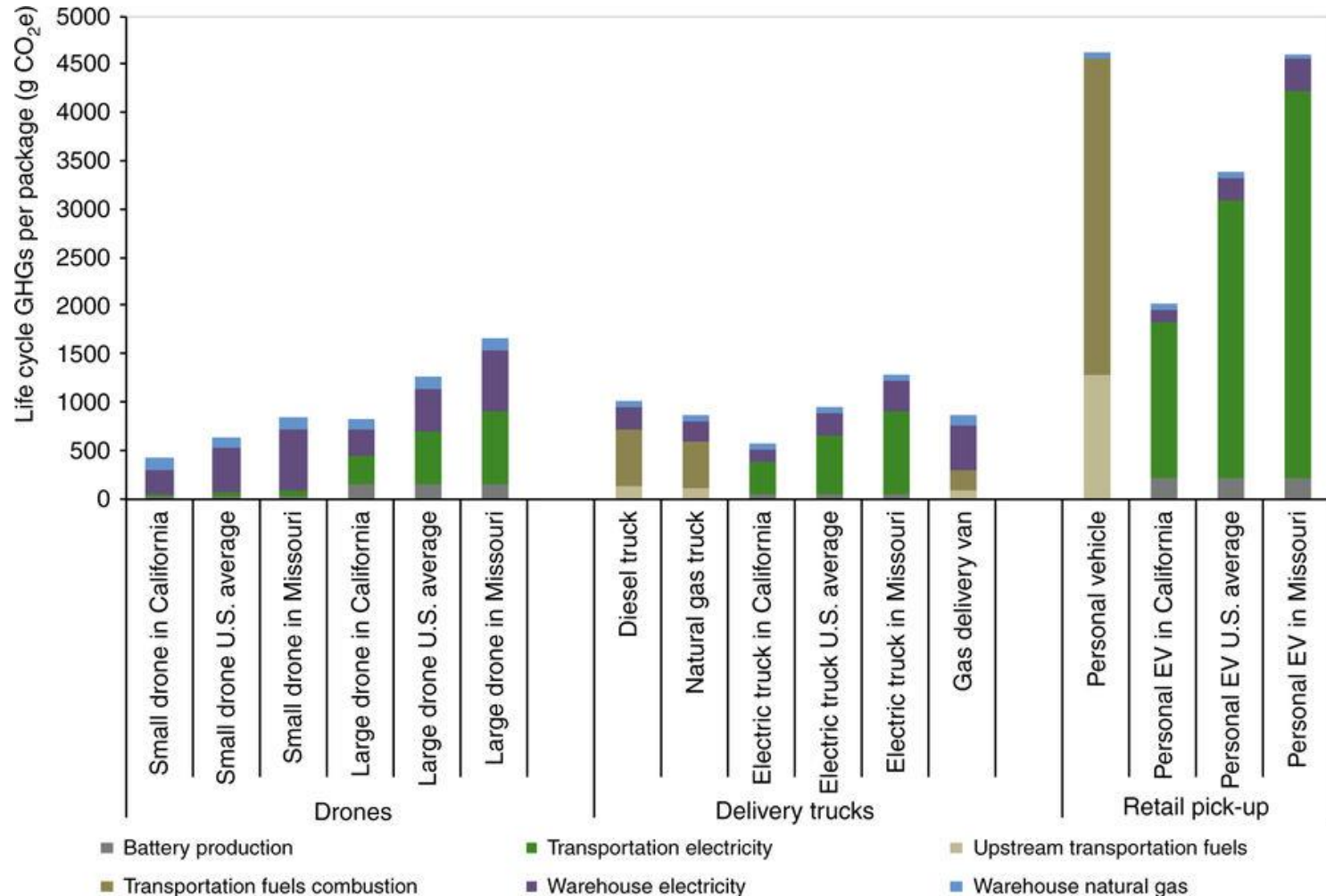
EPA: Glider trucks have far higher emissions than conventional tractors



Sources: <https://www.nytimes.com/2018/02/15/us/politics/epa-pollution-loop-hole-glider-trucks.html> and <https://www.documentcloud.org/documents/4378485-Combating-Pollution-in-Diesel-Trucks-and-the.html#document/p19/a404379> and https://www.dieselnetwork.com/misc/201711_epa_glider_report.pdf

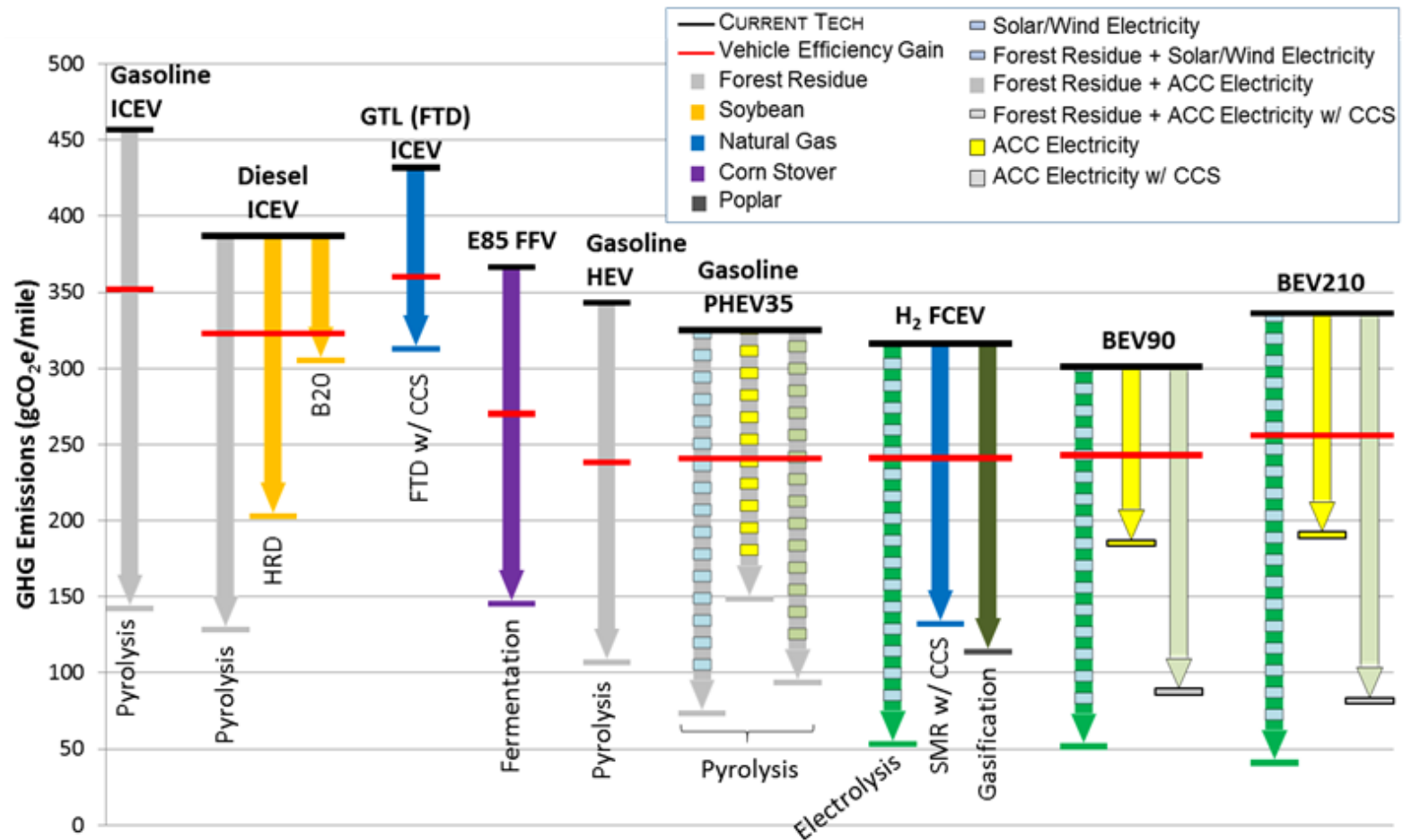
freight emissions

LLNL, CMU, SRI, UC: Delivery by drone has comparable emissions to delivery trucks, better than retail pick-up



LDV emissions

US DRIVE: Improvements in fuels and vehicles can lead to lower GHG emissions in the future



topics

energy markets

automotive markets

technologies studies

environmental studies

5 behavior & opinion surveys

policy & business studies

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5 behavior & opinion surveys

travel behavior

- > FOTW: VMT has grown twice as fast as the driving population since 1950
- > NAS: Rebound effect from improved fuel economy may have increased total VMT by 10%

vehicle purchases

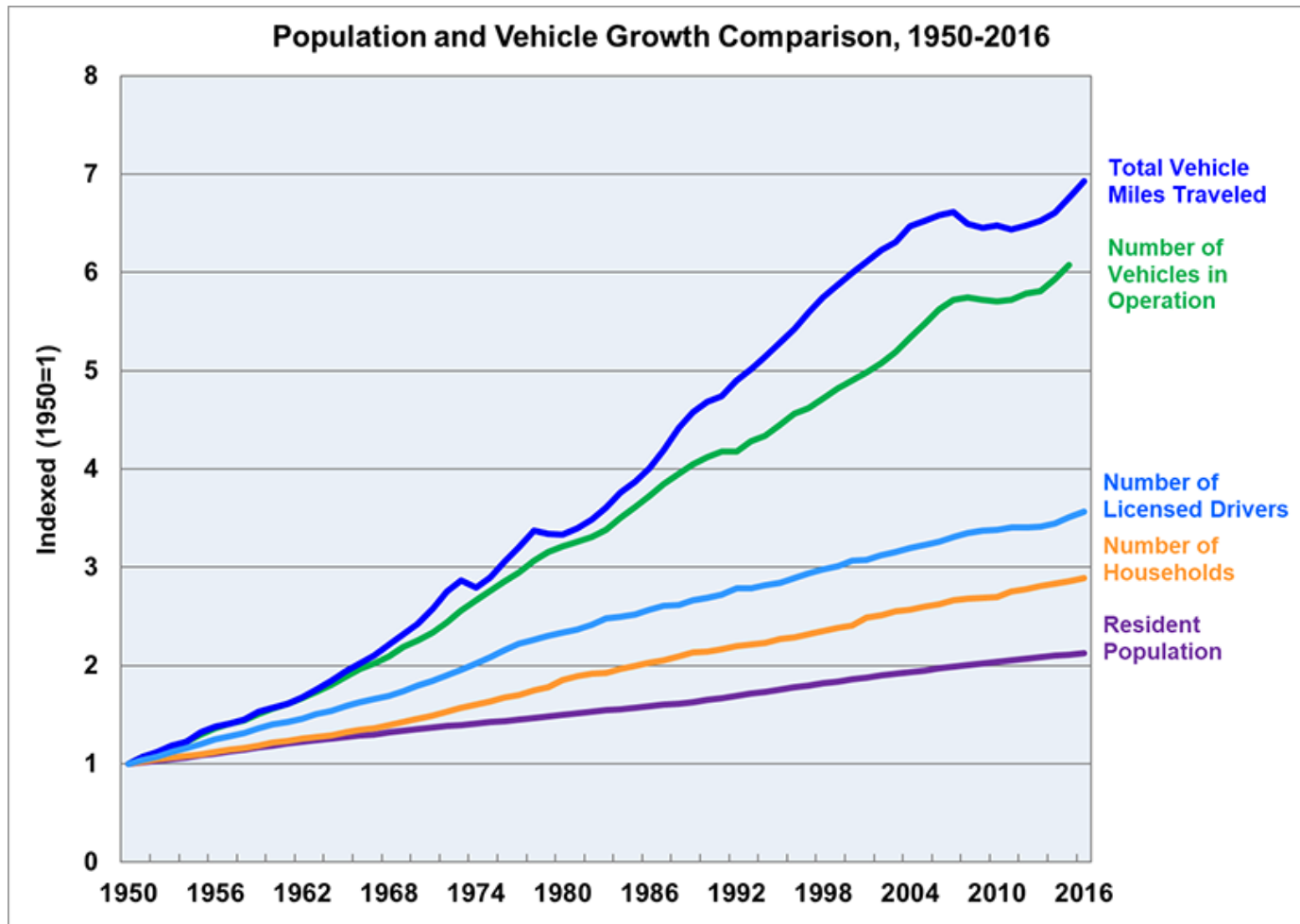
- > Fuels Institute: Fuel economy is one of most influential attributes for vehicle purchase
- > Fuels Institute: Vehicle charging is viewed as biggest impediment to PEVs

CAV sentiments

- > AAA: Americans of all ages are becoming more comfortable with CAVs

vehicle travel

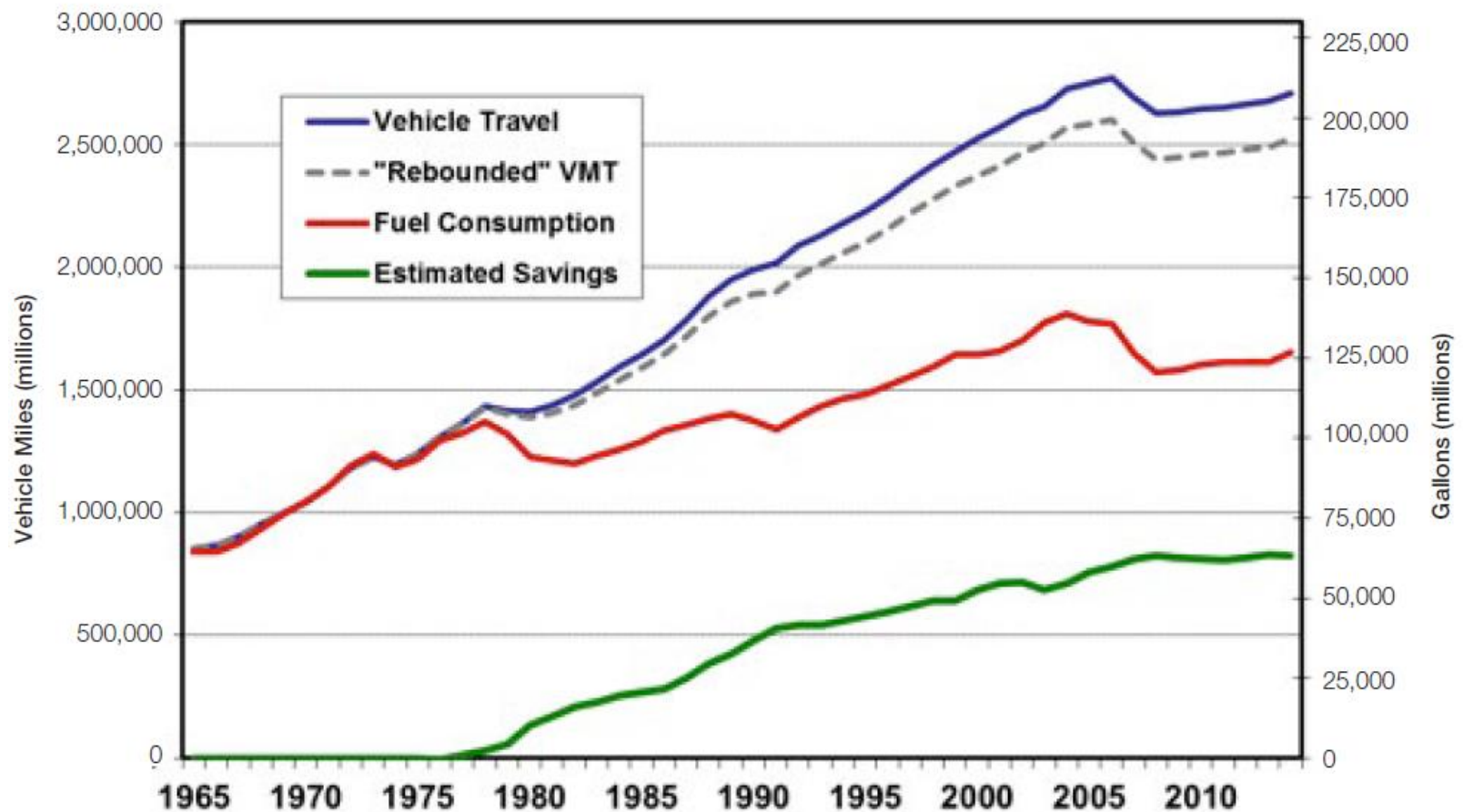
FOTW: VMT has grown twice as fast as the driving population since 1950



vehicle travel

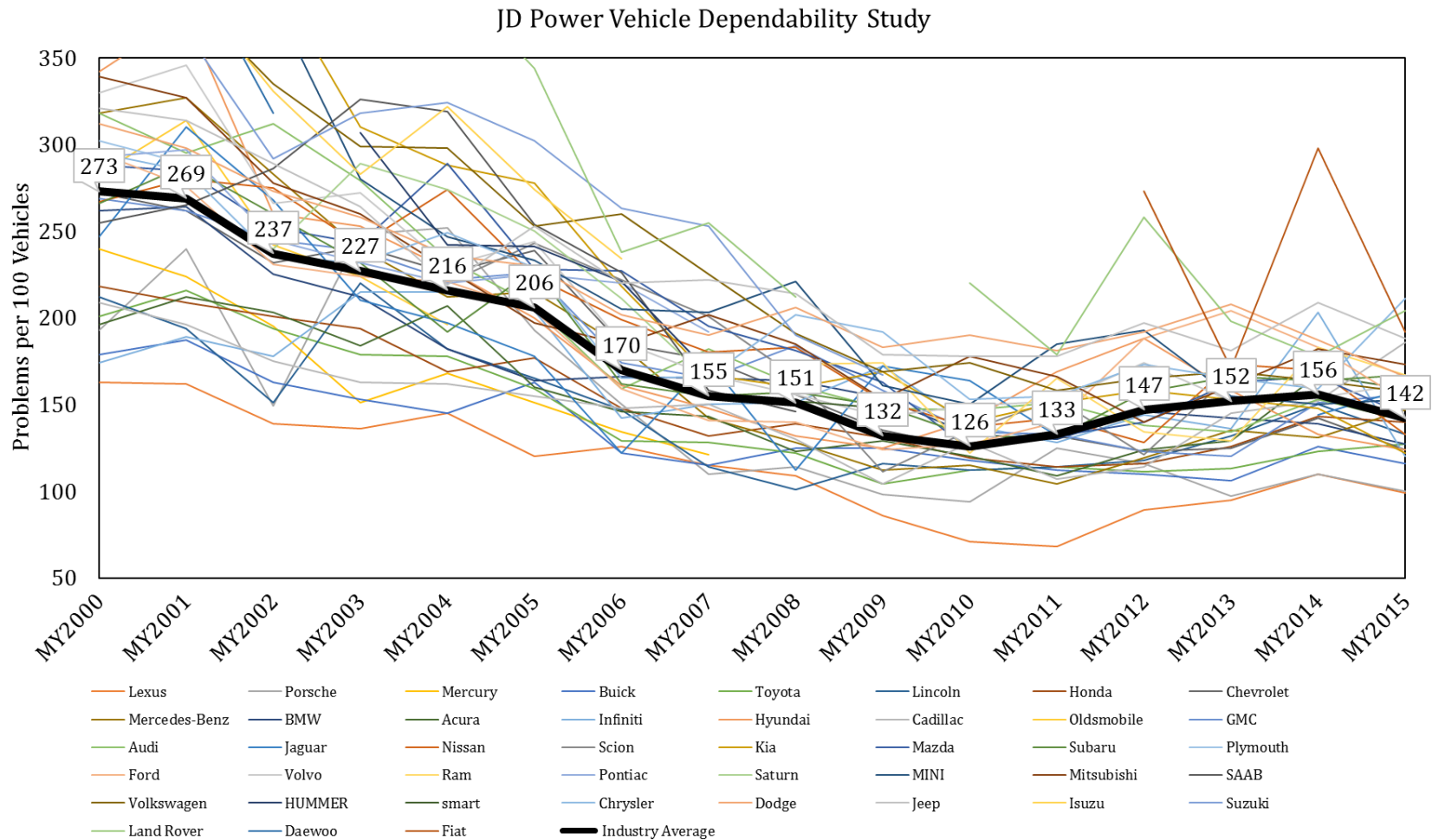
NAS: Rebound effect from improved fuel economy may have increased vehicle travel by 10% since 2000

Miles of Travel and Fuel Use by Light-Duty Vehicles: 1965–2014



vehicle reliability

JD Power: MY2015 had improved perceived vehicle reliability after several years of increased problems

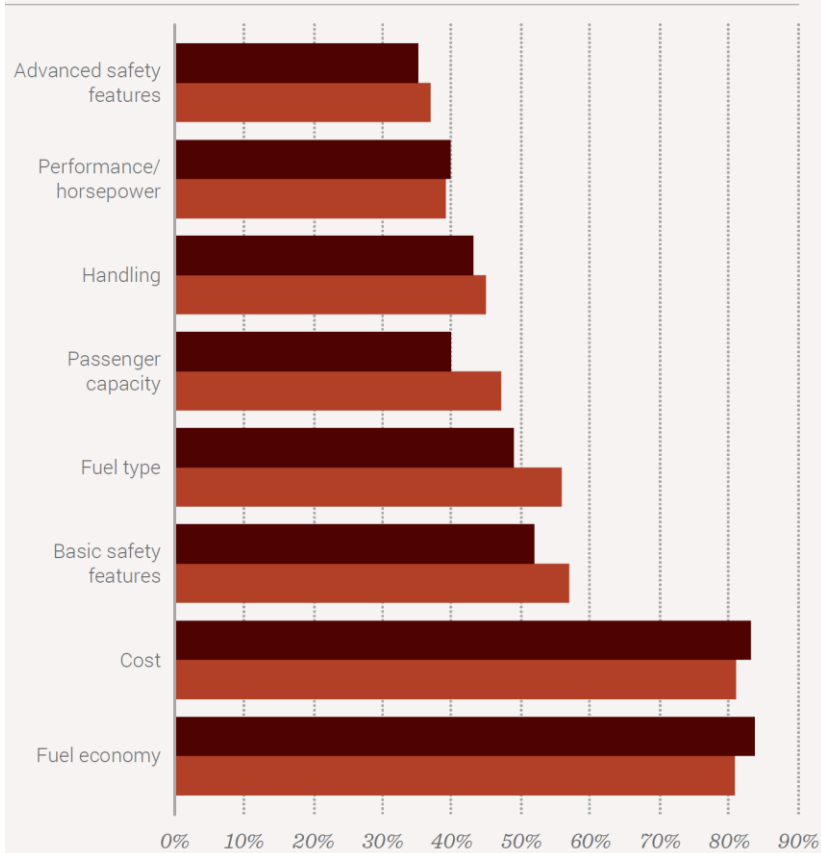


purchase behavior

Fuels Institute: Fuel economy is one of most influential attributes for vehicle purchase

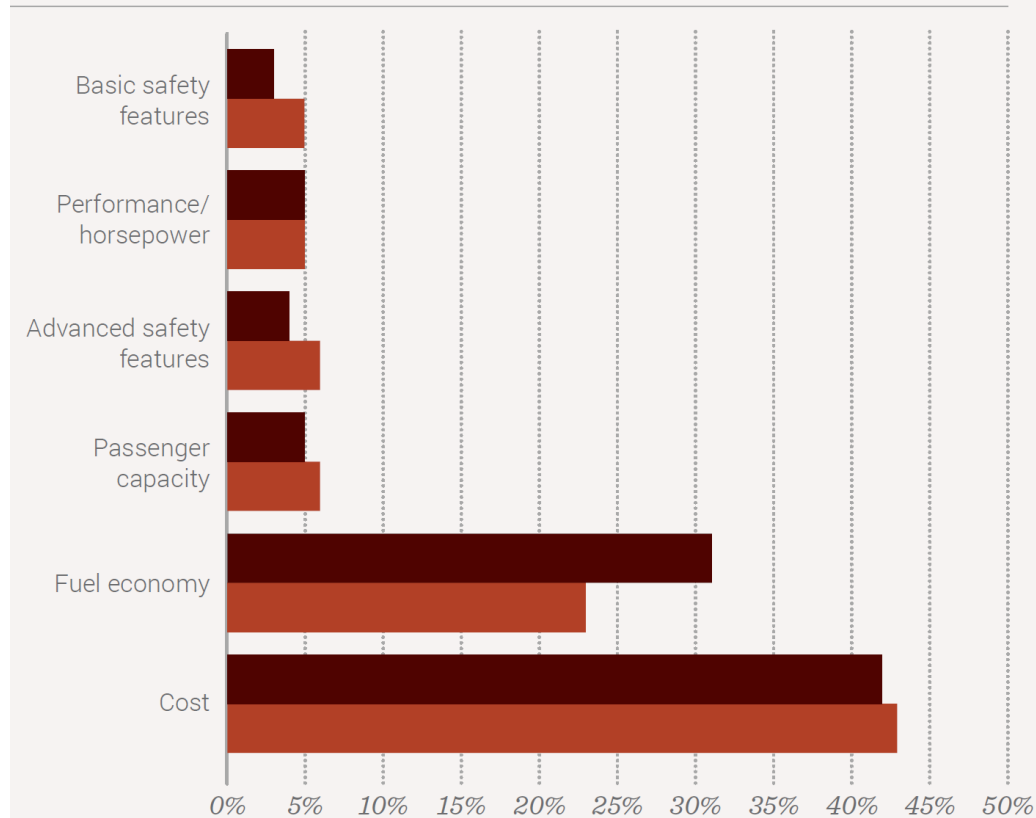
Which vehicle attributes are *most influential*?

2014 2017



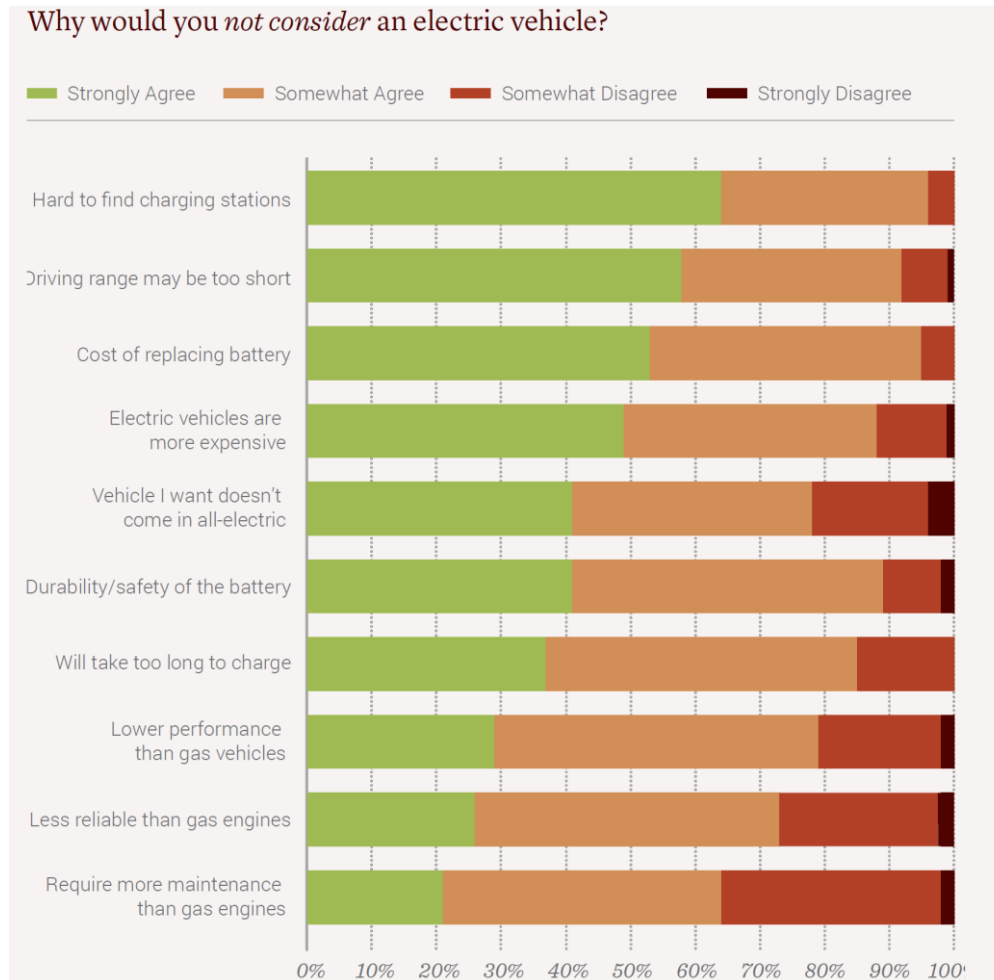
What *single* attribute is most influential?

2014 2017



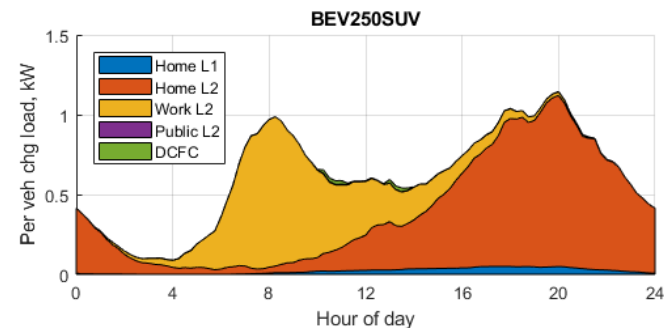
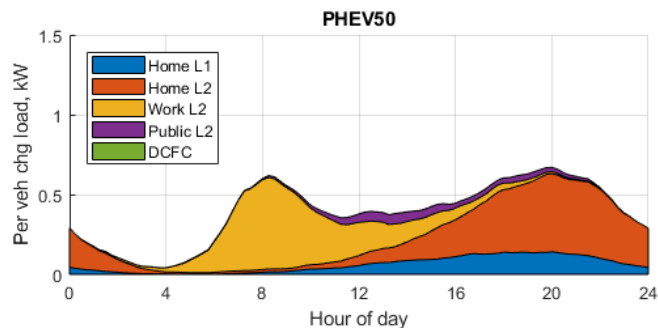
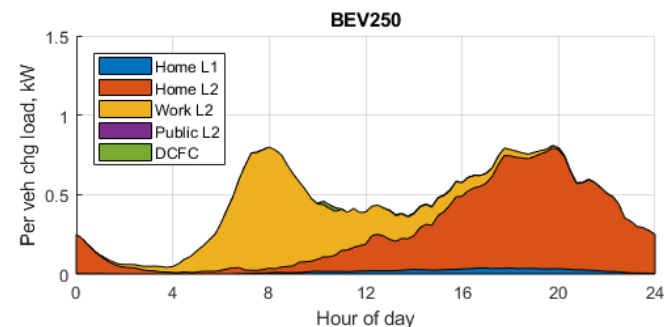
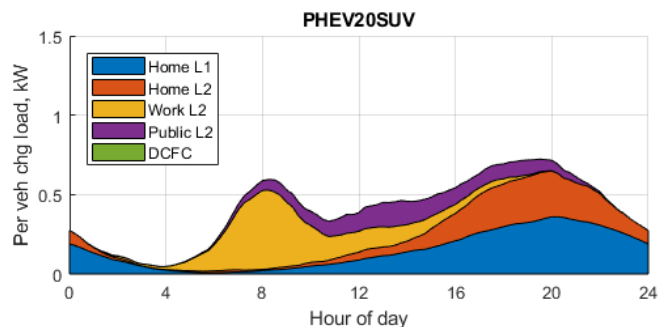
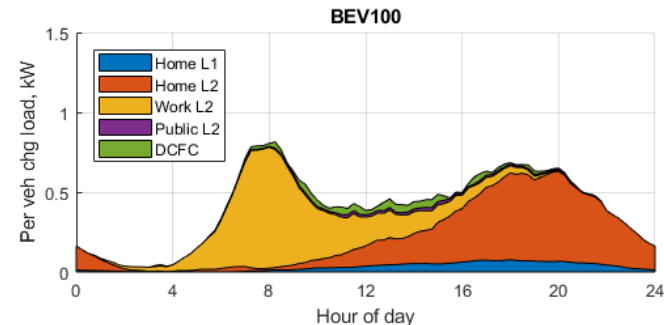
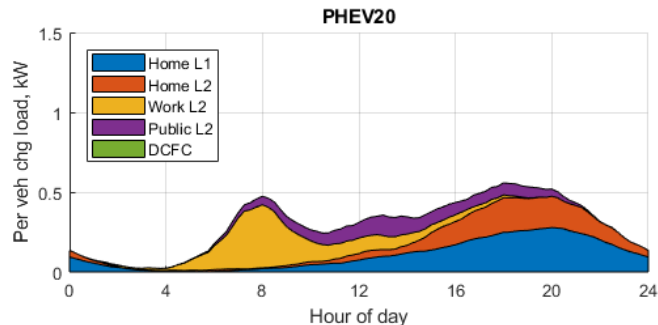
purchase behavior

Fuels Institute: Infrastructure is the top impediment to considering EVs



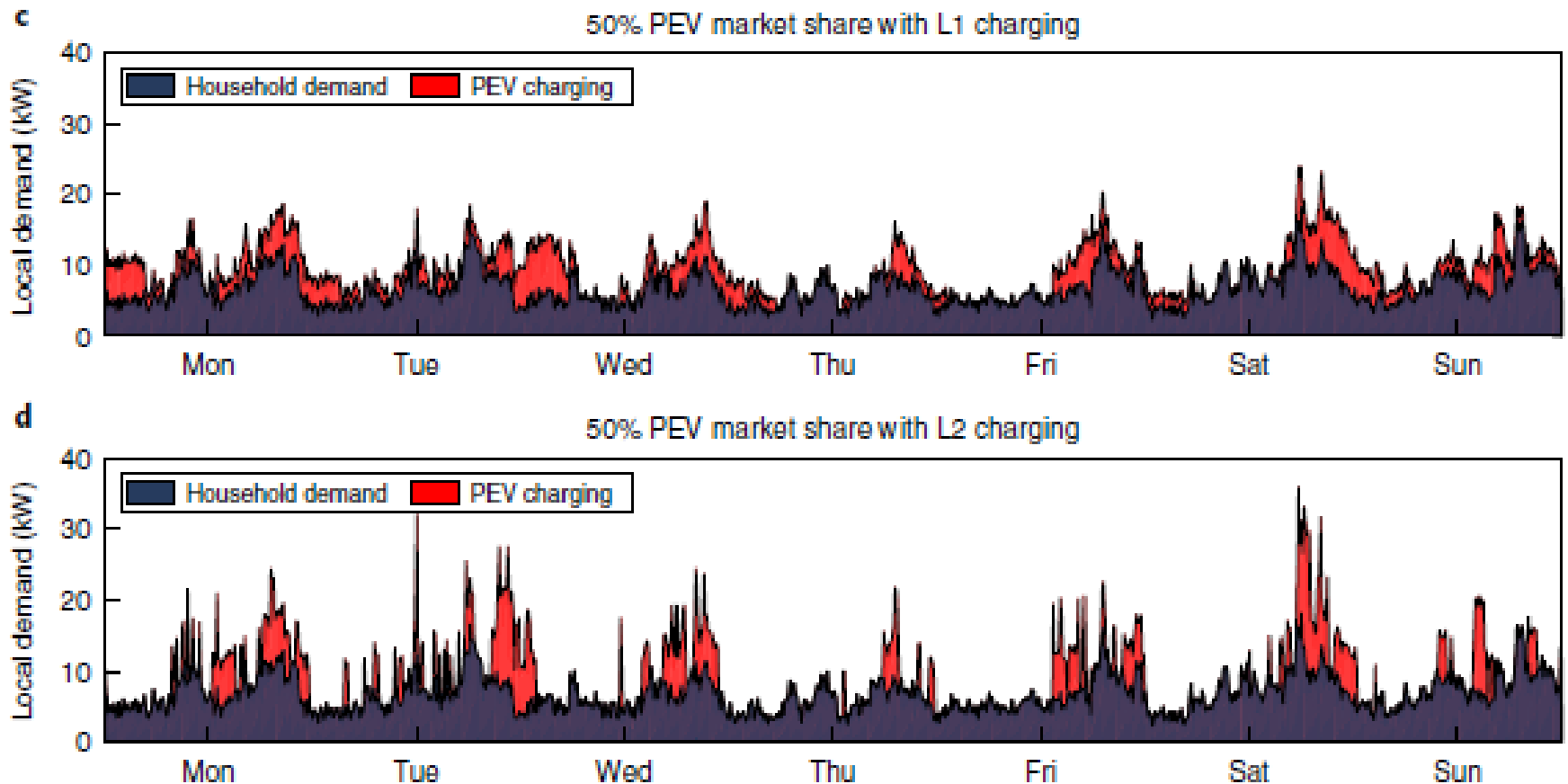
PEV charging

NREL: PHEV and BEV are projected to have different charging profiles in Columbus, OH



PEV charging

NREL: Peak EV charging demand will depend on how people use L1 and L2 charging



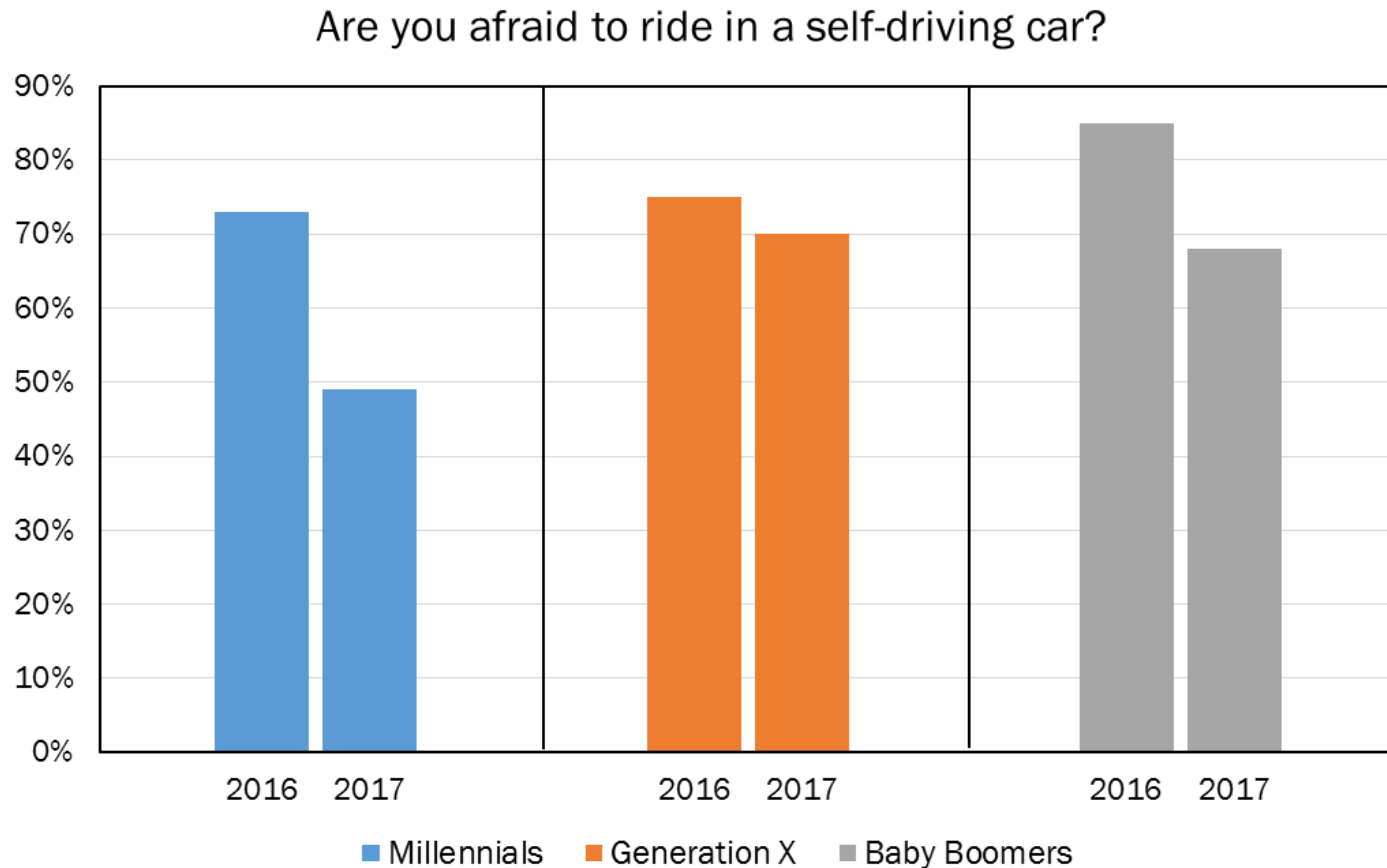
vehicle fueling

FHWA: Compressed natural gas fueling corridors now stretch across most of the eastern United States



CAVs sentiments

AAA: Americans of all ages are becoming more at ease with riding in self-driving cars



topics

energy markets

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employment

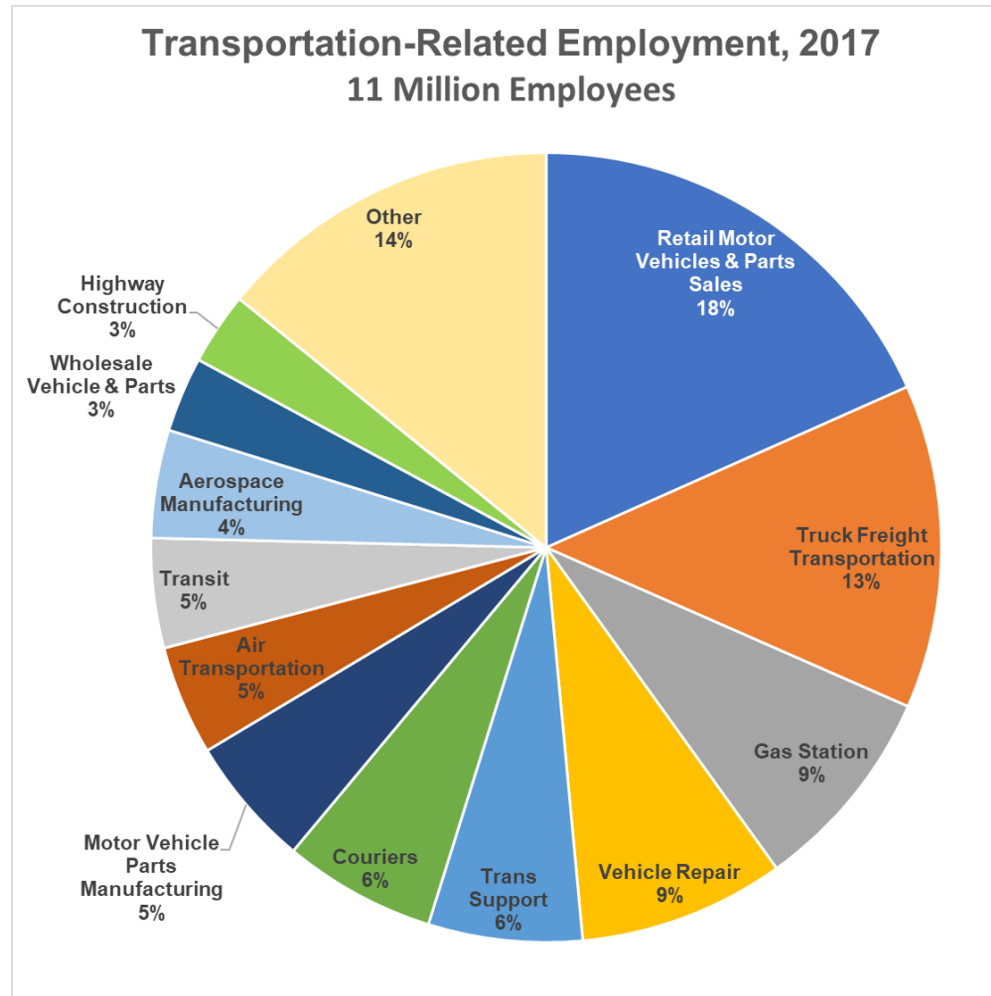
- > FOTW: About 11 million Americans were in transportation-related jobs in 2017
- > FOTW: Transportation-related employment was 16% higher in 2017 than in 1990

fuel economy standards

- > CALSTART: Turbocharging/downsizing and vehicle electrification are viewed as key to meeting 2025 fuel economy standards; electrification viewed as key post-2025

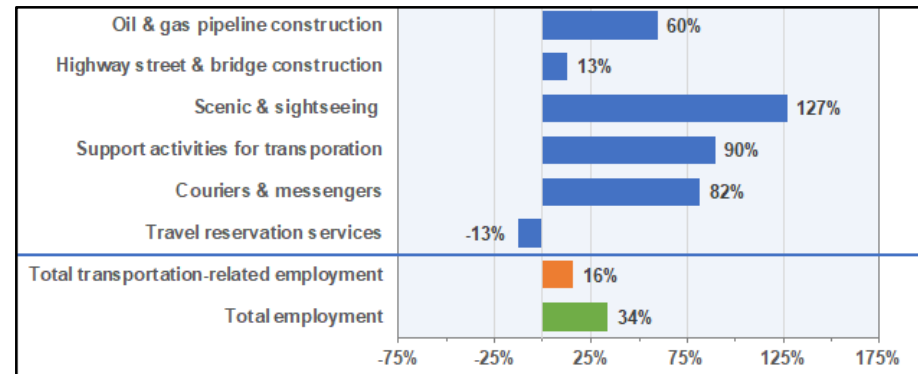
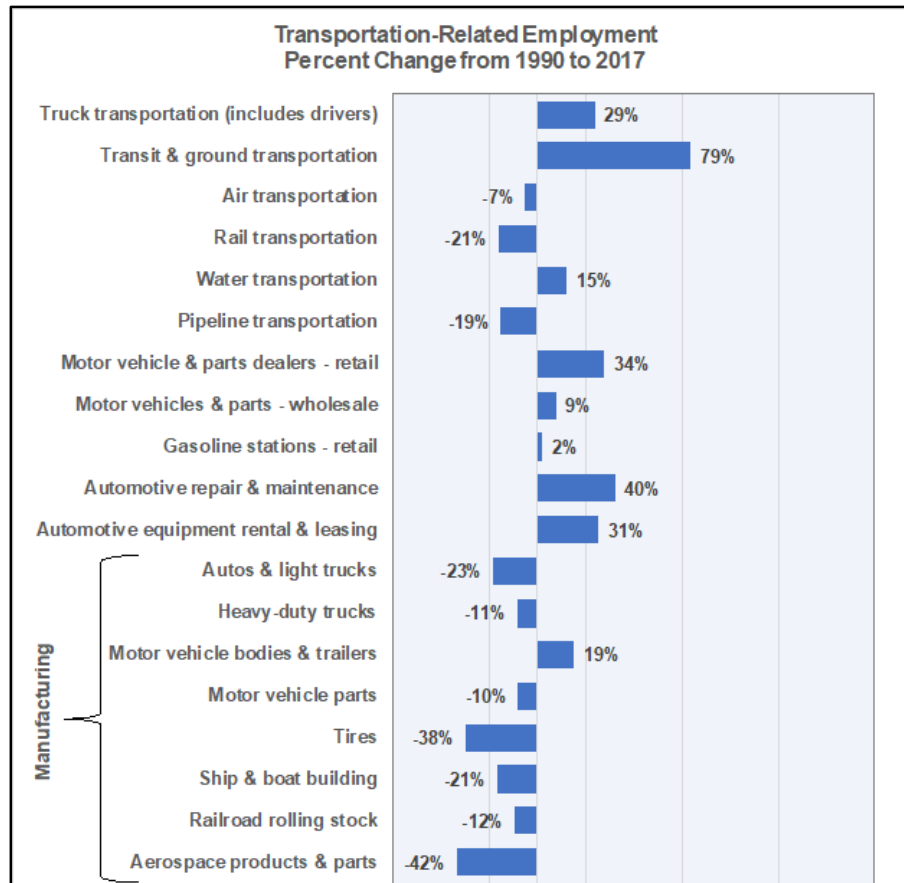
employment

FOTW: About 11 million Americans were in transportation-related jobs in 2017



employment

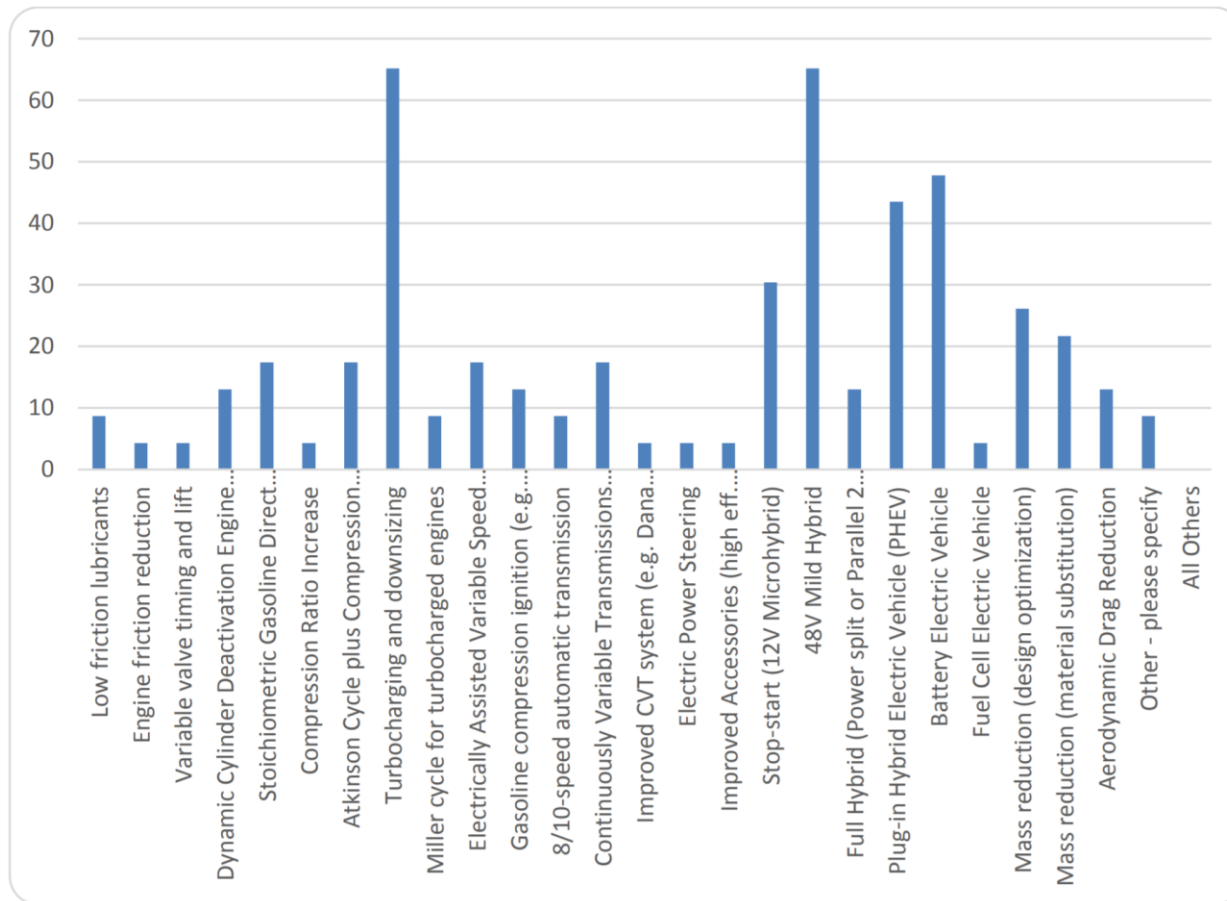
FOTW: Transportation-related employment was 16% higher in 2017 than in 1990



fuel economy standards

CALSTART: Turbocharging and electrification (48V and PEV) are viewed as key to meeting 2025 standards

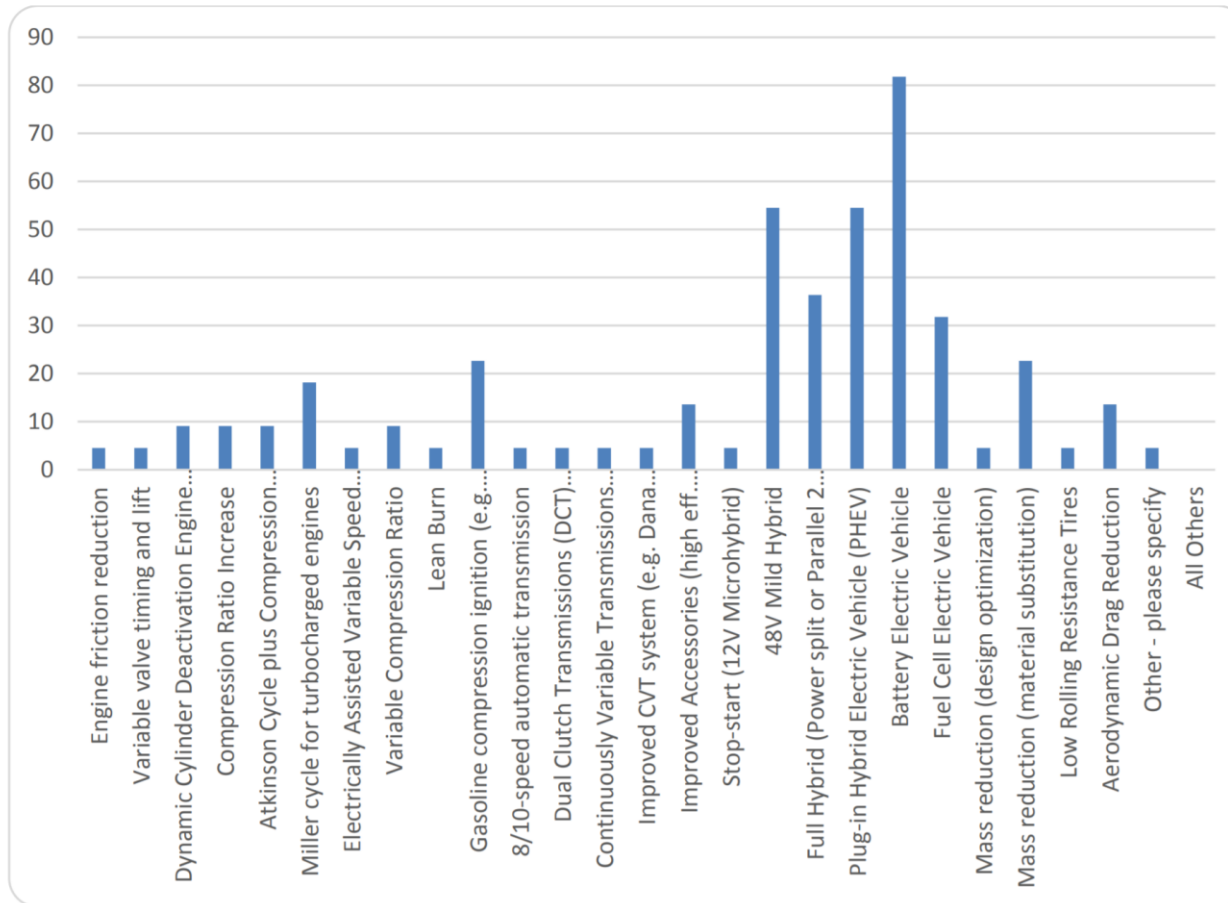
Figure 5 Survey response to 'Which of the following technologies do you view as key for meeting the current US 2025 LDV GHG standards?'



fuel economy standards

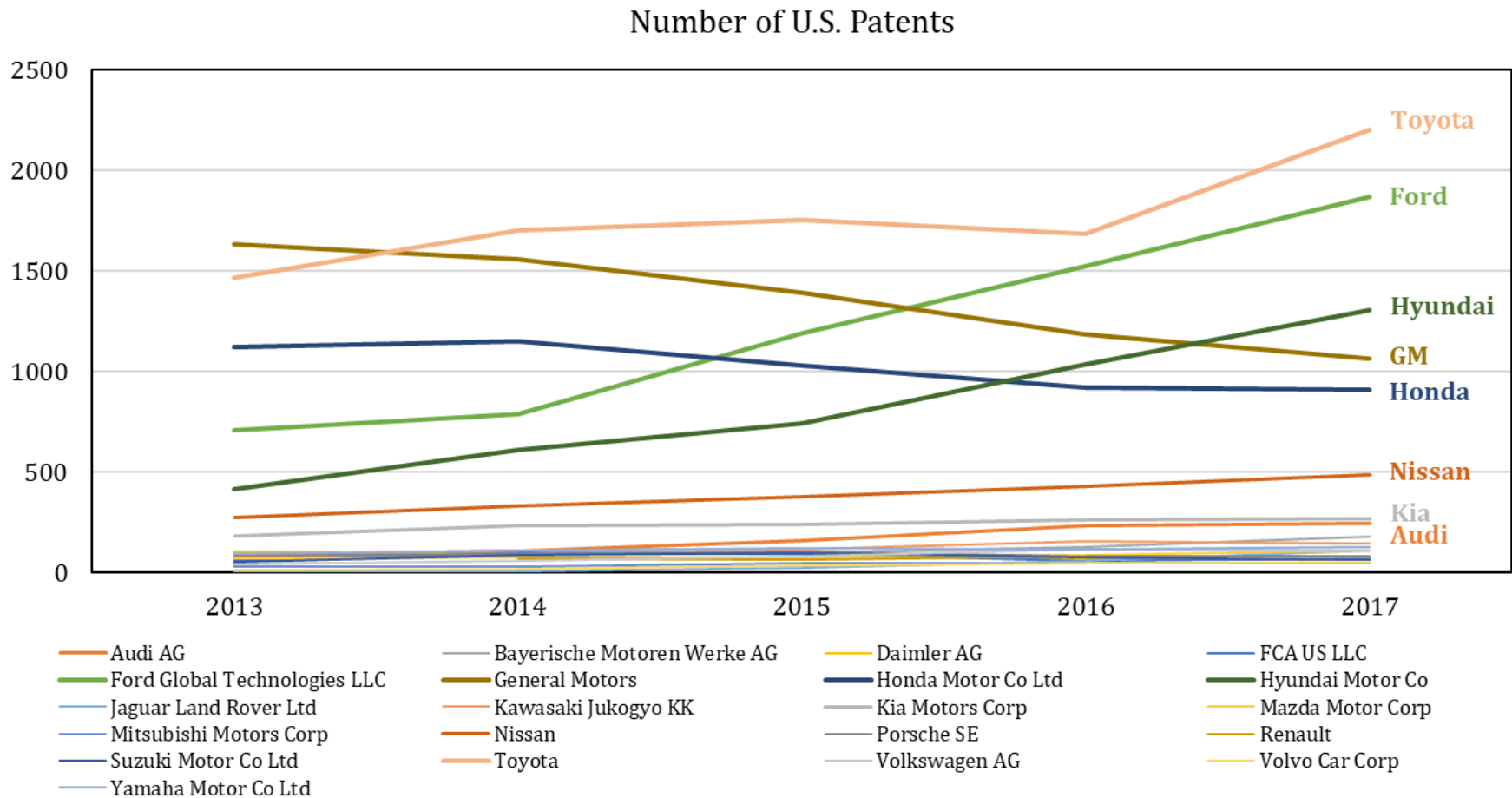
CALSTART: Suppliers see electrification as key for post-2025 fuel efficiency improvements

Figure 6 Survey response to 'Which of the following technologies do you view as most relevant for the post-2025 period (2026 - 2032)?'



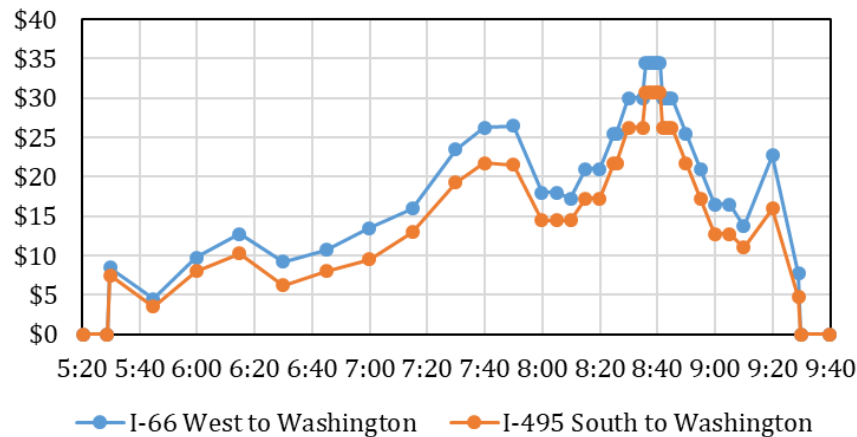
intellectual property

IFI Claims: Toyota and Ford are leading way for most total U.S. patents by automobile manufacturers

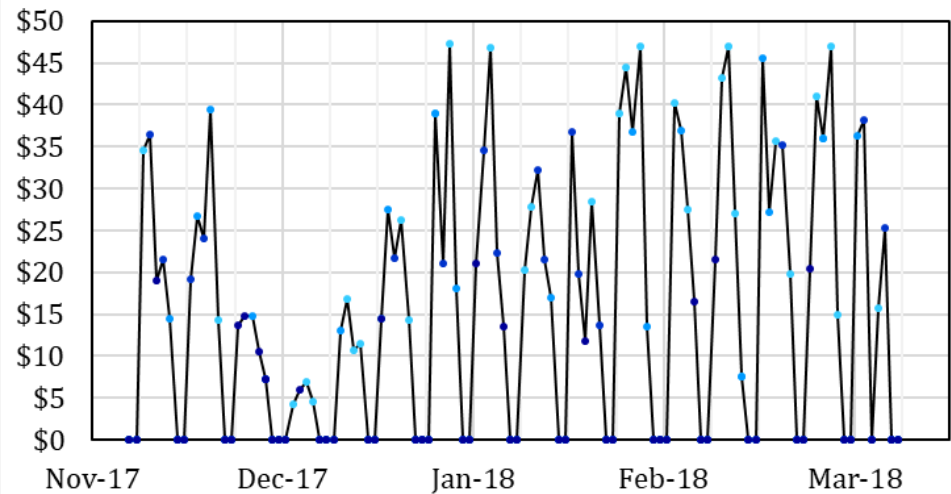


VDOT: After being opened up to solo drivers, dynamic tolls often peak above \$30 one-way on I-66 in Virginia

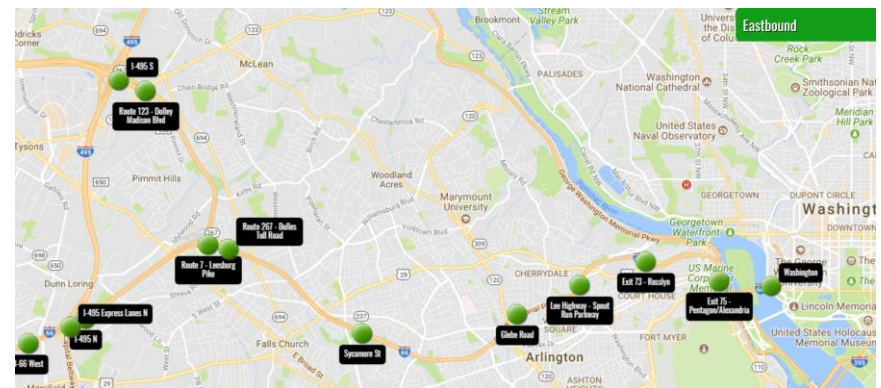
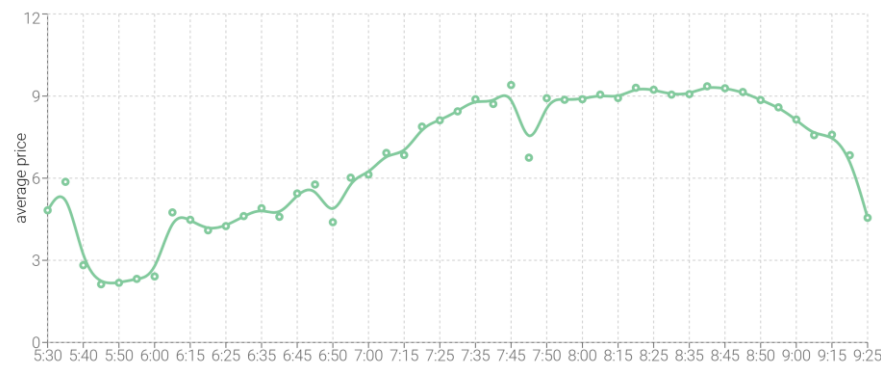
I-66 Tolls, December 4, 2017



Peak Morning I-66 Tolls



Beltway to Washington by time



Source: <https://vai66tolls.com/#> and <http://shoulditakei66.today/analytics/>

summary observations



energy

U.S. petroleum production is at its highest point in decades; on-road vehicles consume majority of transportation energy

automotive

New LDV market slightly off from last year, while used LDV and PEV markets at record highs

tech/enviro

U.S. fuel economy continues to set record highs; EIA's AEO 2018 projects continued improvement in fuel economy; CAVs and drones raise unique emissions considerations

opinion/policy

VMT at all-time high in U.S.; PEV charging infrastructure is viewed as important component of purchase behavior; 11 million Americans work in transportation-related jobs

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summary